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PRODUCT ENGINEERING

McGRAW-HILL WEEKLY FOR DESIGN ENGINEERS • JANUARY 2, 1961

Shock and vibration test on fuel and oxidizer system of Atlas missile

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- BEGINNING—9 LECTURES ON MECHANISMS . . . page 25
- THESE WAYS TO SOLVE INTRICATE DIECASTINGS . . page 36
- SAFE TOLERANCE FOR CUMULATIVE DIMENSIONS . . page 40

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PRODUCT ENGINEERING

McGRAW-HILL WEEKLY FOR DESIGN ENGINEERS

January 2, 1961 Vol. 32, No. 1

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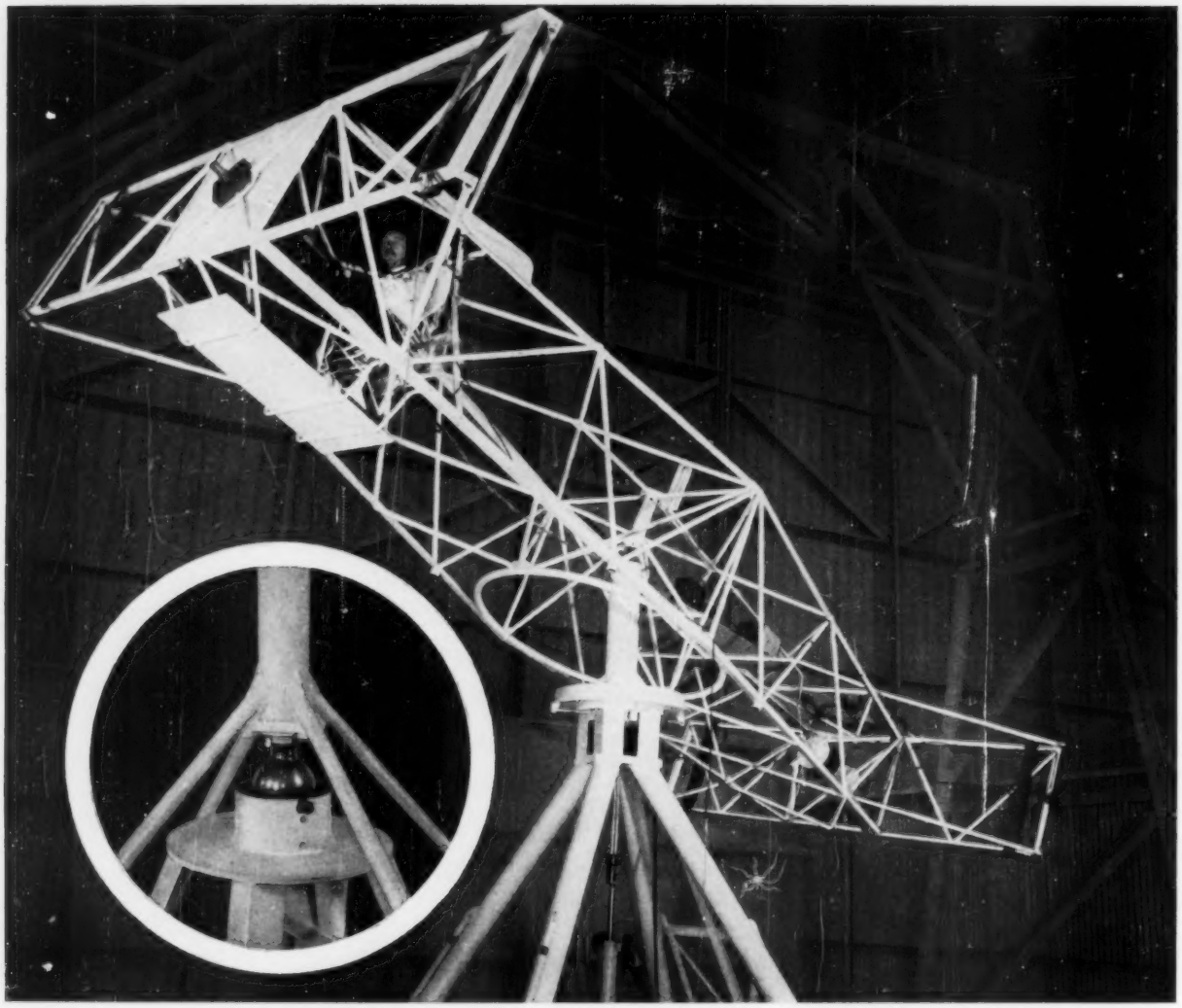

MAKE-BELIEVE FLIGHT—Much of the feeling of flight in a space vehicle is experienced during a ride in this reaction-control simulator, being put through its paces at Boeing Airplane Co., Seattle, Wash. The simulator rides atop the nickel alloy steel ball plated with Nickel in Boeing's ball-and-socket type air bearing.

Space simulator gives the "feel" of flight

Nickel-plated ball of high strength steel supports reaction-control test vehicle

This earthbound space machine is designed to test ways of controlling a vehicle as it pitches, rolls and yaws in the airless reaches of outer space.

In action, the simulator and its payload of test equipment can weigh as much as 5,000 pounds. Yet the necessary sensitivity is achieved by floating the unit on an air-cushion bearing made of a high strength nickel alloy steel ball in its socket.

Imagine this 2½-ton load resting on a ball about the size of a grapefruit! The ball, made of nickel alloy steel heat treated to a tensile strength of 180,000 to 200,000 pounds per square inch, stands up to the load. To provide a hard, smooth surface, the ball is plated with one-thousandth of an inch of Nickel. This uniform surface keeps air leakage in the bearing to a minimum.

Remarkably durable, Nickel and its alloys offer practical solutions to problems of stress, fatigue, abrasion, corrosion or temperature extremes. Used in alloys, in plated coatings or by itself, Nickel helps make possible many new products and processes—and can help improve existing ones—by providing unique combinations of properties.

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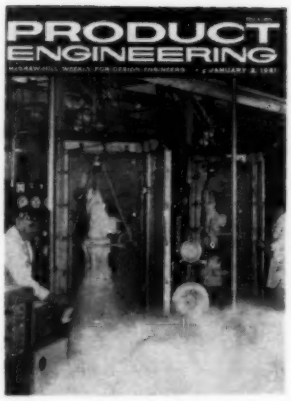
INTERESTING TO NOTE



On our cover—A test of fill and drain systems for the fuel and oxidizer in an Atlas missile. Photo was taken at Phoenix, Ariz plant of AiResearch Manufacturing Co. Liquid nitrogen simulates the oxidizer, so test temperature reaches down to −320 F. Movement simulated is that of swaying on the launch stand while loading, coupled with the expansion and contraction from temperature variations, and the shock of disconnect-action when missile is fired. General conformation can be seen in the unfrosted system at right. Traditional testing has been concerned with one variable (or "environment," as the missile makers say) at a time. But this isn't good enough to meet present-day reliability requirements, so more and more testing now involves multiple variables.

In most cases, missile testing can be accomplished without endangering human life. In the case of manned space probes, or the testing of experimental spacecraft like the X-15, safeguarding the men involved becomes a serious problem. In fact, when the X-15 established a new altitude record, its test pilot, Scott Crossfield, came close to losing his life before he ever took off.

The book, *Ninety Seconds to Space—the Story of the X-15* tells the details. It seems that when Crossfield ground-tested his oxygen gear he neglected to open his oxygen valve completely. And to complicate matters, as he went ahead with additional ground tests, nitrogen, the gas used to cool the pressure suit, began leaking into his helmet through a break in a rubber seal. Crewmen working on the plane suspected nothing—neither did Crossfield. But soon he felt himself slowly slipping into semiconsciousness. Fortunately he was somehow able to signal for help, and was saved just seconds before the nitrogen would have suffocated him.

From Jail to Geology

Over the years, geology has attracted men trained originally in other fields. Of the great geologists, Lyell and Silliman were lawyers and Agassiz was a zoologist. And Amos Eaton, considered by many to be America's first great teacher of geology, entered the field after spending time as an attorney, a land agent—and a convict.

Eaton was born and raised in upstate New York, graduating from Williams College in 1799. He went to New York City to study law, reading books on chemistry, botany and "natural philosophy" in his spare time. After being admitted to the bar, he took a job as land manager and rent collector. However, within a few years, young Eaton was accused of forgery by an unscrupulous ex-tenant. The case dragged through the courts for months. The

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evidence against Eaton was completely false, but still a jury found him guilty and imposed a life sentence.

Eaton became a unique kind of prisoner. He preferred books on botany to regular prison activities and in time was given privileges not granted to others. His studies took him deep into botany and mineralogy. In time, he became fascinated with the geology of New York State. Soon some influencial friends, including DeWitt Clinton,

then mayor of New York, had the life sentence commuted to four years.

As soon as he left prison, Eaton enrolled at Yale, where he studied botany, chemistry and mineralogy. After completing his studies, Eaton accepted a position at Williams College, lecturing on mineralogy and botany. With the money he saved while teaching, he took a 200-mile walk from Massachusetts to New York, noting the geology of the area. In the evenings, Eaton gave free lectures to the townsfolk in the village he happened to be passing through. After finishing this trip he published one of the most complete geological reports ever presented at that time.

The geologist today no longer has the problems that confronted Eaton. Teams of men that search out data have replaced the lone researchers; and computers have taken over the job of processing information. Graphs, not unlike those discussed on page 44, are plotted to answer questions concerning the age of strata, depth of minerals and location of faults. Gulf Oil Corp scientists estimate that they can manipulate more data in one year than geologists have succeeded in handling over the past 150 years. Where formerly a man working steadily for some 18 months would transfer oil-well data from sheets to a printed graph by hand, a computer now does the job in three hours. —Benedict A Leerburger Jr

SIDELIGHT

Last month the New York Central Railroad took a great step forward. It announced approval of an American-made railroad wristwatch for official use throughout the system. In the past, most railroads have required operating employes to carry an officially inspected pocketwatch.

The era of the conductor reaching for his big gold "ticker" has passed. Commuters now hope that with a new, more accurate timepiece, trains will finally meet their schedules. One commuter recently lamented that the reason fares were getting higher and higher was because trains were getting later and passengers were paying for the additional time they were spending aboard.

NEXT WEEK IN PRODUCT ENGINEERING

. . . **Foreign Engineers Don't Argue Patent Rights**
Special Report, from McGraw-Hill news bureaus, contrasts your patent situation with that in six other nations.

. . . **Don't Overlook Near-standard Fasteners**
These specials, varying only slightly from the standard, can save assembly time and money.

. . . **Equations Find the Right Impeller**
Once the airflow, static pressure and rpm are determined, just a few simple calculations will show the type and size of impeller needed.

. . . **Spring Mechanisms—Point Balancing**
Graphical methods show how springs with plain lever mechanisms can balance load moments at four precision points.

. . . **What You Can Do with Flexible Magnets**
Bend them or die-cut them to shape. Perhaps use them as seals too. Here's an introduction to a widening field.

. . . **Proper Preload for Cam-follower Springs**
Charts and equations quickly determine the right preload for harmonic and parabolic cams.

WHAT'S HAPPENING IN RESEARCH . . .

Stress cracking: plastics experts outline causes and cures

Stress cracking of high-density (linear) polyethylene is still an unsolved problem; but its effects can be minimized, Belgian, US, and British representatives told the Stockholm conference on Plastics Technology.

Stress cracking may result from **mechanical strains** (inherent in design or introduced during molding); **chemical action** which lowers surface tension and permits intermolecular attacks; **ultraviolet radiation** that generates free radicals and leads to polymer degradation; and heat aging, which results in oxidation and eventual embrittlement.

Where heat, light, or chemicals pose problems, formulations can be selected which offer better-than-usual performance in these respects.

On the mechanical side, design attention to such points as section thickness, location of metal inserts, and methods for support or attachment (following standard principles of good casting design) can do much to prevent failure of parts in service.

To minimize molding strains, one method especially recommended by Belgian researchers is changing the diameter of the molding sprue. Impact failures were reduced from 30% to less than 10% simply by changing from a thick sprue to a thin, pinpointed one. Close control of molding pressure and temperature resulted in still further reductions, with relatively high cylinder temperatures, low mold temperatures, and short pressure cycles giving the best results.

Coming to grips with thermal terms

Emissivity and emittance, and other terms that deal with thermal radiation are defined and clarified in a 17-page report from Defense Metals Information Center.

It notes that **emissivity** is actually a limited term, which should be applied only to radiation from opaque bodies having optically smooth surfaces and the lowest rate of emission.

Radiancy is the broadest term—the rate of radiant-energy emission from a unit area of a source in all the radial directions of the overspreading hemisphere.

Emittance is the ratio of rate of radiant emission from a body (as a consequence of temperature only) to the corresponding rate of emission from a blackbody at the same temperature. (A **blackbody** is an ideal emitter which radiates energy at the maximum rate per unit area at each wavelength for any given temperature. It also absorbs all the radiant energy that is incident upon it.)

Copies of the 17-page report, DMIC #72, may be obtained without charge by government contractors and suppliers direct from DMIC. It will later be available to others from OTS, Dept of Commerce, Washington, DC as PB161222. Price will be approximately 50¢.

Complex graphite parts by pyrolitic conversion

Graphitization of plastic parts after fabrication, to produce "graphite" parts by simple molding techniques, is under study in the Soviet Union. It's a way to get around the machining problems posed by graphite itself and thus produce more-complex components.

The idea is basically similar to that used in making flexible "graphite" fabrics in the US (*PE*—May 4 '59, p 7); and starting point is a synthetic organic resin. In the case of solid, structural parts, the resin would likely be a phenol formaldehyde.

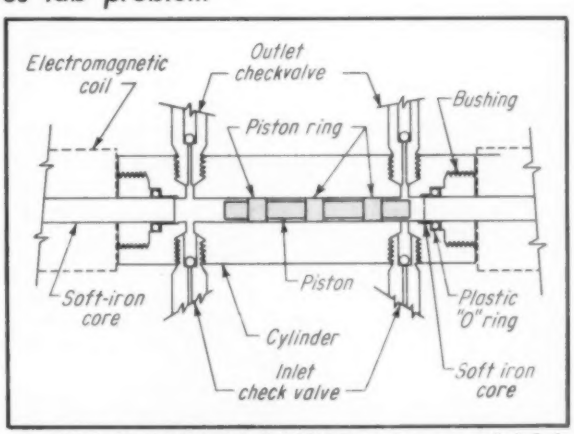
The work in the Soviet Union is still in its early stages, with isotope studies being made to explore the graphitization mechanism. A report on this phase of the work, by V. D. Moiseyev, appeared in *Plasticheskiye massy*, #6, 1960. —ARC

Simplified pump solves lab problem

With a plastic-coated household magnet for a piston, a pair of electromagnets, and a nonmagnetic stainless steel cylinder, researchers at Air Products Inc have built a simple electromagnetic pump for circulating gases at low flow rates. It has only 3 moving parts, yet is able to hold system volume constant, and prevent contamination.

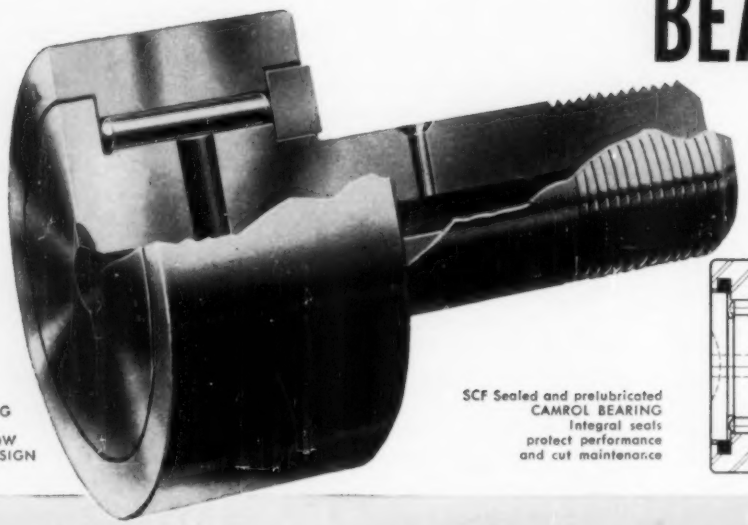
The piston is readily reversible (by reversing the polarity of the electromagnets) and the pump is made double-acting by use of inlet and outlet valves on both ends of the cylinder. O-rings are machined directly from the plastic coating on the piston, and the plastic itself (PTFE fluorocarbon) serves as a lubricant. The checkvalve balls are the only other moving parts (see diagram).

The associated electrical circuit, as described by C. J. Sterner of Air Products in *Review of Scientific Instruments*, has a motor-driven timer with two cams to provide 2 pulses/sec, each pulse lasting less than 0.2 sec. Direct current flows through the electromagnetic coils, its direction being reversed at each pulse.



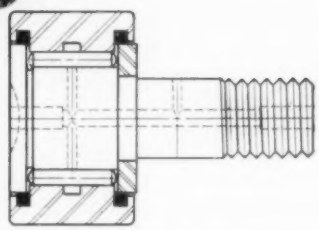
PLASTIC COATING ON MAGNET serves as seal, lubricant, and packing in this small electro-magnetic pump. The magnet is a small bar of the type used in magnetic stirrers. Cylinder and bushings are stainless steel.

McGILL® CAMROL® BEARINGS



CF CAMROL BEARING

CUT AWAY TO SHOW INTEGRAL STUD DESIGN



SCF Sealed and prelubricated CAMROL BEARING
Integral seals protect performance and cut maintenance

SIMPLIFY DESIGN and ASSEMBLY

Stock sizes eliminate the cost of procuring and assembling improvised unit components

You can simplify design and cut cost with CAMROL precision anti-friction cam followers—built for the job. Complete units, with established performance ratings are available from stock in standard roller diameters from ½" to 4". Capacities to 20,480 lbs. at 100 R.P.M.

Precision anti-friction bearing accuracy

Precision construction, including concentricity of stud to outer race OD, provides accurate alignment of machine members.

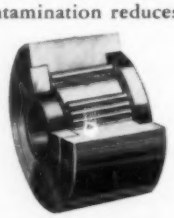
High load capacity in limited space

A full complement of race width rollers provides maximum capacity and ability to withstand heavy intermittent shock loading. The extra heavy outer ring and specially heat treated stud add durability and insures dependability of machine operation. Bolt mounted ball bearings crack under equivalent loads and plain bearings require constant oil lubrication.

Integral seals retain lubrication —keep dirt out

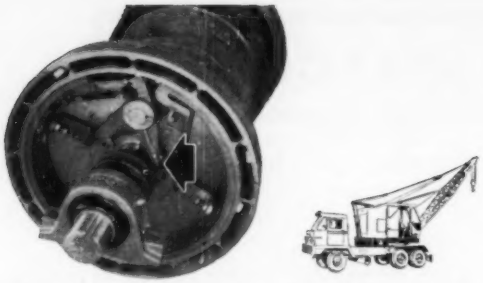
SCF Sealed CAMROL bearings are interchangeable dimensionally with standard CAMROL bearings. They are pre-lubricated and have a ferrous oxide finish to resist corrosion. Effective sealing against contamination reduces machine maintenance.

Camrol CYR series



In the CYR Series, an inner race replaces the stud for yoke or shaft mounting. Standard and sealed CYR bearings are available in the same stock sizes as CF and SCF Series.

SEND FOR McGILL BEARING CATALOG NO. 52-A. for complete data on McGill CAMROL, GUIDEROL, MULTIROL and CAGEROL bearings.



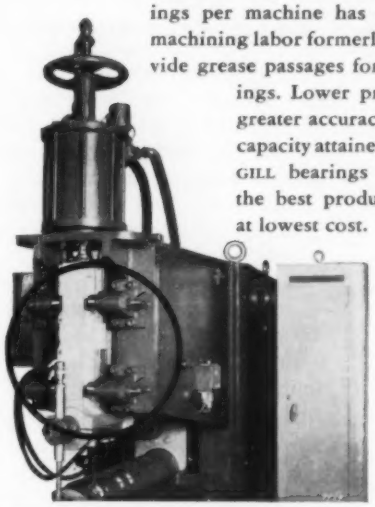
SCHIELD BANTAM UTILIZES CF BEARING ADVANTAGES IN VARIETY OF APPLICATIONS.

The Schield Bantam Company has applied CF bearings in internal clutch band operating arms, turn controls, swing and travel shaft clutch cones, engagement controls and speed shift collars. The photo above shows how CF-1 bearings are applied to Drum Clutches in Schield Bantam Series 350 cranes and shovels.

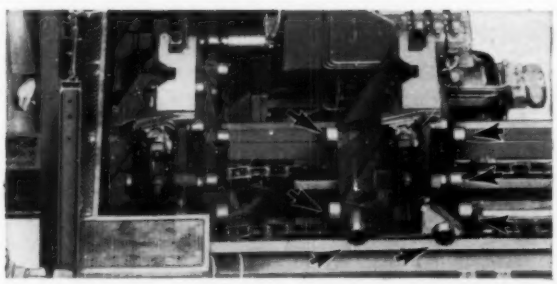
This company replaced bronze collars and yokes and reports cost savings through the use of CAMROL bearings. In addition they have increased capacity and have experienced improvement in length of life and maintenance factors. This has added to the over-all efficiency and dependability in heavy equipment where "down-time" is extremely expensive.

ACRO WELDER REDUCES PRODUCTION COSTS, IMPROVES ACCURACY WITH SCF BEARINGS

SEALED CAMROL bearings are used to accurately locate and guide the welding ram in spot welders made by ACRO WELDER MFG. CO. The user reports that the use of 12 prelubricated CAMROL bearings per machine has saved hours of machining labor formerly needed to provide grease passages for unsealed bearings. Lower production costs, greater accuracy and high load capacity attained with these McGILL bearings help to assure the best product performance at lowest cost.

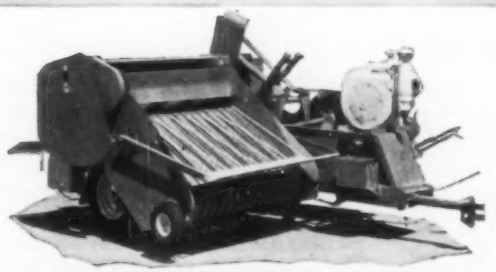


— insure precision performance in cam follower, track and guide roller applications



BUHR MACHINE TOOL CUTS FRICTION TO REDUCE HORSEPOWER WITH SEALED CAMROL BEARINGS

Production parts are drilled, milled, bored and tapped in automated systems engineered and built by the BUHR MACHINE TOOL COMPANY. The moving fixtures which hold parts being machined are guided and carried on McGill sealed CAMROL bearings as shown in the close-up above. By reducing starting and running friction to an absolute minimum, the CAMROL bearings have made horsepower requirement reductions possible in these systems. Ample load capacity, high resistance to shock loads and integral seals which retain lubricant and keep out contamination have held maintenance down. 8 SCF-3 CAMROL bearings guide and support each fixture.



J. I. CASE USES SCF AND SCYR CAMROL BEARINGS IN HAY BALER

The bale compressing plunger of the J. I. Case Model 177 Heavy Duty Hay Baler rolls on CF-2¾-S CAMROL Bearings and CYR-1¾-S Bearings guide the plunger.

Anti-friction bearing dependability and trouble-free performance are essential in this type of field equipment where bearing failure may result in loss of valuable harvesting time.

Integral bearing seals in these CAMROL bearings, keep relubrication requirements low and protect internal bearing components from field dirt, dust and moisture.

In addition to accurate, dependable action with minimum friction, high quality McGill CAMROL bearings offer savings on production and assembly.

engineered electrical products

McGILL®

precision needle roller bearings

MULTIROL-GUIDEROL-CAMROL-CAGEROL

McGILL MANUFACTURING CO., INC., Bearing Division
201 N. Lafayette Street, Valparaiso, Indiana

DEVELOPMENTS TO WATCH...

Variable-speed motors claim high efficiency

Two repulsion-type single-phase motors, working in tandem and housed in a single case, provide a variable-speed motor that's said to be unusually efficient because it has no mechanical transmission losses (power takeoff is directly from the motor shaft), and permits continuous speed variation over a range of 0 to 6000 rpm and instantaneous reversal without switching.

Each motor has its own, electrically independent armature, though the two are mounted on a common shaft, and they have independent commutator and short-circuiting brush assemblies.

Speed control and reversal are obtained by rotating both sets of brushes simultaneously in relation to the fixed stator fields. This can be done manually (with a single hand wheel), or by means of an electronic control unit.

Brunt Variable Speed Motors Ltd, Chadderton, Oldham, England designed the unit, and is producing it in sizes from 2 to 25 hp. Prices (US equivalent), with electronic control unit, tachometer, and motor contactor, range from about $500 to $1680.

Plutonium goes commercial

The nuclear, man-made element plutonium makes its debut today as a commercial-industrial material. But, unlike most materials, it will increase rather than decrease in price as it assumes its new status. As a research material, it carried a developmental price of $12 a gram. Now it will be $30 to $40 a gram. But it will be available for such industrial use as calibration of nuclear instruments.

Information on the material and its application may be obtained from AEC operations officers.

Canadians to test watercooled transmission systems

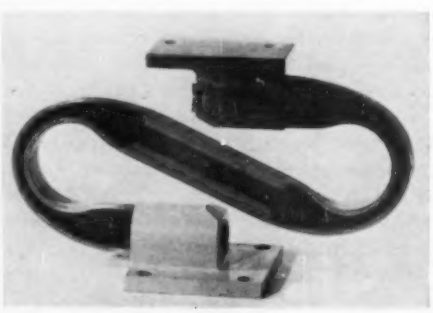
A new opportunity for design could open up if a test installation of a watercooled electrical power-transmission system, now planned by Ontario Hydro, proves successful. The aim: to permit higher transmission loads. The test involves watercooling of underground cables via plastic tubes lying between the cables, in direct contact with cable sheaths. Among the components now being developed for use with the system are automatic flow controls, and stand-by leak detectors, for use when the system is not in operation and therefore not under pressure. The flow controls will have solenoids activated by a temperature-sensing device attached to the cable sheath, or current-sensitive relays supplied by a transformer around one of the cables.

Self-damping spring protects sensitive equipment

A spring that looks like a bourdon tube, and serves as its own damping mechanism, has been designed by Ets. Domage of Paris (France).

As described by its manufacturer, the unit is so arranged that shock loads applied to it compress the elastomer hydrostatically, much as would a piston operating in an hydraulic cylinder. Viscous friction dissipates much of the applied energy, making the unit self-damping.

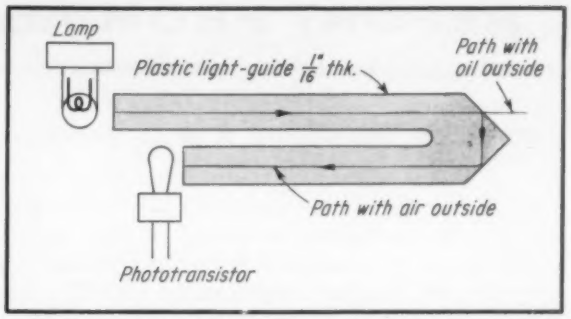
Single and double-acting models (see photo) are made in sizes to handle loads to 2 tons, and can stand operating temperatures from −58 to 248 F. A 660-lb unit measures 4½ by 7½ by 2½ in.



DOUBLE-ACTING SHOCK MOUNT looks much like an S-shape bourbon tube, has a natural-frequency range of 3 to 5 cycles. Photo shows a demonstration cutaway. Special seal prevents extrusion of the elastomer.

Oil-level detector uses photo-transistor, plastic light-guide

A level-detector which uses the total internal reflection in a light-guide made of acrylic plastic to indicate the level of oil in a tank is said to be unaffected by ambient temperature and simple in construction. It's part of an oil-flow calibrating rig developed at Britain's National Engineering Laboratory, East Kilbride, Glasgow. Key to its operation is the thin plastic light-guide—so thin that, when in contact with the oil being monitored, its light ceases to be reflected internally and, instead, passes into and through the oil, in effect cutting off the light to the transistor (see diagram) and indicating that the liquid has reached the preset check point.



PLASTIC LIGHT-GUIDE is key element in new liquid level detector. When immersed in oil, light goes straight through upper arm of guide; does not reach photo-transistor. When the guide is above oil level, internal reflection carries light around the U, illuminates transistor, and provides monitor signal.

Alloying is key to commercial zirconium use

Zirconium's stock falls and columbium's hopes rise as nuclear reactors head for higher temperatures, says J. R. Pfann of Stauffer Chemical. As he pointed out to a recent Chemical Market Research meeting, zirconium's major use today is in nuclear reactors; but higher temperature requirements for the nuclear reactors of the future may mean that zirconium will be replaced within the next five years by one of the newer refractory metals such as columbium, or by special grades of stainless steel. Most likely, he predicts, columbium will be the material of choice.

What, then, for zirconium? The outlook is not as bleak as it might seem. New alloys now under development will, he believes, open up non-nuclear applications, though it's likely to be quite a while before demand pushes present 1400-ton-a-year sponge capacity any higher.

Controllable-pitch blades being readied for ships

King-size controllable-pitch propellers are being designed for the US Maritime Administration. The aim: to permit travel ahead and astern without reversing the engine—simply by changing the pitch of the propeller blades with a system similar to that employed on aircraft.

The prototype model, to be used for system evaluation, will be a 20,000-shp unit, operating at about 105 rpm. It will be a 4-blade, right-hand unit, about 22 ft dia, and its shaft will be designed to replace the tail shaft and one section of line shafting in a conventional system.

The blades themselves will be activated by a hydraulic system, using positive-displacement pumps and automatic servomotors. Pitch-indicating systems and controls are also to be designed. The indicating system for bridge instalment will be an electrical synchro setup, and that for the engine room will be either hydraulic or pneumatic.

Detailed design and tolerance specifications have been drawn up and work should be underway early this year.

New input for human brains?

The eyes and ears aren't enough, says Richard Newman of Rome Air Development Center (RCSHG), to answer communications needs in many of today's military situations, so a new system is being tried; transmission of information through the skin. Using the natural vibratory response of the skin, he believes, it will be possible to transmit "processed" speech, by a system which will require relatively simple training for the receiver and none for the sender.

Exploratory studies have indicated why previous efforts in this direction have not been successful and have shown how a feasible system may be developed. Now under study: effects of transitionals and other distortions that occur in formation of words, and of high-frequency speech chopping selective-frequency band amplifications and filtering.

—ARG

REPORT FROM ABROAD . . .

French boost nonmilitary R & D spending by 20%

Funds for government-sponsored, nonmilitary research in the 1961 budget approved late last month by the French National Assembly total slightly more than $107 million, an increase of 20% over 1960 credits and nearly double the 1958 figure.

Included in the 1961 credits is first slice of the $65 million authorized for a 5-year supplementary research program to strengthen French science in advanced disciplines where it is lagging. For the first year of the program, the big efforts will come in space research, oceanography and molecular biology.

In space research, about $6 million will be spent during the year to develop instrumentation for data-gathering missile shots. (The missiles themselves are being developed by the armed forces.) Another $2.65 million will be spent to start construction of two oceanographic vessels. In molecular biology, the effort will start with coordination of work being done in government and university labs.

The 1961 funds also include $1 million for crash research programs that may become necessary during the year.

British report success with single-engine, orthodox airframe VTOL

Recent untethered hovering flight of the Hawker Siddeley P1127 successfully demonstrated a single-engined VTOL (vertical take-off or landing) configuration having an orthodox airframe which permits normal horizontal alignment at takeoff without swiveling the engines or the wing.

The layout depends on the relatively simple expedient of swiveling the extremities of the jet nozzles only. The aircraft is powered by a 17,000-lb thrust turbofan—the Bristol Siddeley BS 53.

The fan flow and the hot gas flow pass unmixed out of separate bifurcated nozzle at the front and rear of the engine. Rotating elbows at the nozzle extremities give a thrust vector within an arc extending from the horizontal to a position slightly beyond the vertical (reverse thrust). Geometry of the nozzle hinges ensures that the thrust reaction passes through the aircraft center of gravity for all flight altitudes, thus simplifying the control requirements.

The BS 53 is one of the first engines designed from scratch to exploit turbofan principles. Main feature is a high fan ratio of 2 to 1. The fan is front-mounted and supercharges the compressor. A mechanical complication requires contra-rotating spools to eliminate gyroscopic coupling which would call for substantial yaw correction in the hovering attitude.

Germans industries neglect applied research

The training of young engineers, chemists, physicists and mathematicians for essential R & D responsibilities is being criminally neglected by private industry in West Germany, say responsible Bonn officials. This is because insufficient money is being channeled by the consumer- and capital-goods industries into development work.

Through 1960, the German consumer-goods industry spent between 1% and 2% of its turnover on development. The capital-goods industry channeled slightly less than 10% into development work. These moneys are barely sufficient to effectively tackle current scientific and technological problems in the nation.

However, through 1961 the German Research Association plans to earmark about one-third of its estimated $25-million budget for applied research, one-third for basic research and the remainder for improving and modernizing old facilities, or erecting new buildings for the various technological institutes. The association has also fostered the formation of a nonprofit agency for contract research designed to aid small and medium-size industrial firms needing R & D assistance.

THE ENGINEERING WEEK

Hopes Ride High for Supersonic Passenger Liner

The Sunday supplements are losing a favorite subject. Bell Aerosystems has just completed a feasibility study that says commercial aircraft operating at almost-orbiting speeds of 15,000 mph are technically and economically possible—not simply a blue-sky fantasy. Here are some engineering data from that study.

WASHINGTON—Commercial aircraft equipment capable of covering the 10,200 miles between New York and Melbourne, Australia, in 1 hr 22 min is technically feasible and could be available by 1980, in the opinion of engineers at Bell Aerosystems Co, Buffalo. They base their views on an analysis of the problems—structure, material and propulsion—involved in design of supersonic craft.

As Bell envisions it, a supersonic passenger system would be a 30-passenger craft that would take off, piggyback style, on a huge booster vehicle. At 20-mi altitude, the passenger craft would blast off the deck of the booster, and climb to 300,000 ft propelled by its short-lived rockets. After rockets burn out (in about 4 minutes), the transport would go on to its destination 10,000 mi away, at about 15,000 mph.

WING MATERIAL FOR REENTRY

One of the major problems that must be solved for such craft is how to dissipate the tremendous heat that comes during reentry. A shallow reentry flight path that avoids the extremely high peak temperatures encountered by ballistic missiles could partly solve the problem. However, the lower temperatures extend over longer periods of time.

At present, reentry heat is expected to cause the leading edges of the wings and fins of the transport rocket to glow white hot. This problem, Bell says, cannot be solved by ablative systems because of the changes they would cause in weight and shape. One answer might be using a blunt leading edge, 3 in. dia or larger, and high swept-back wing angles (65 to 75°). Leading-edge temperatures may thus be limited to 3000 F, Bell estimates.

Oxidation resistance, strength to resist aerodynamic forces, resistance to thermal stresses, etc., are characteristics desired in leading-edge materials. Consideration is being given to both graphite and silicon carbide, Bell Aerosystems says, because tests have shown that both meet the requirements for leading-edge protection. The graphite, however, has low mechanical strength and must be coated to prevent oxidation, and silicon carbide has a high machining cost.

DOUBLE-WALL CONSTRUCTION

Another structural problem that Bell has tackled is thermal protection for outer walls of the wings and fuselage during reentry. A double-wall concept appears the best approach.

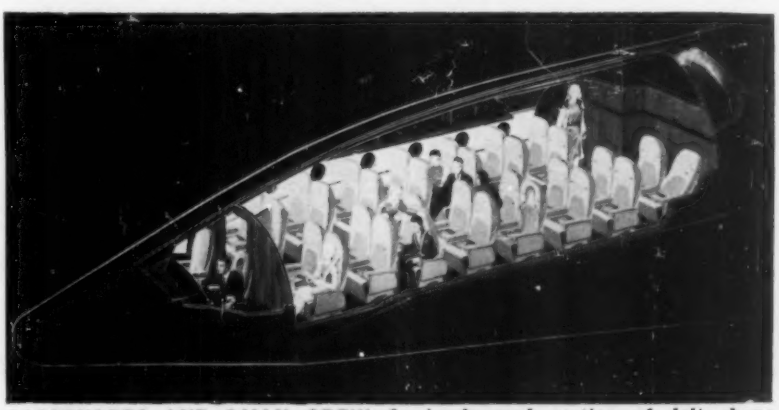
Basically, it consists of an outer wall and an inner wall, with intermediate layers of thermal insulation. The outer wall is a multi-element surface built up of small panels fabricated from heat-resistant materials. The inner wall is formed by the outer skin of a conventional airframe fabricated from aluminum alloy or similar material. The double-wall concept employs a radiative type of thermal protection, the outer wall functioning as a heat shield because of its high thermal emittance. Up to 98% of the friction heat can be dissipated, the company says. But even the 2% that gets through to the inner wall is excessive for long periods.

To cool the primary airframe, integral cooling passages must be incorporated in the inner wall. A suitable heat-transport fluid, such as an aqueous propylene-glycol solution, could be circulated through these passages in a closed-loop system feeding through a heat exchanger. Heat input to the airframe is finally absorbed by an expendable coolant such as water, which is vaporized and exhausted overboard.

Advantages of the double-wall structure are these, Bell says: relatively long exposure to temperatures over 2000 F can be sustained; the primary structure is maintained at low temperatures, thus avoiding strength and stiffness reductions during reentry; a cool environment is provided for passengers and equipment inside of the craft; the outer wall of the vehicle serves as an effective shield against micro-meteorites and prevents puncturing of pressurized compartments.

High reentry temperatures would make any type of windshield in the pilot's compartment incandescent and useless for visual flying, the company says. To overcome this a sliding heat shield will be provided. It could be closed during reentry, then opened for approach and landing.

The entire structure of the booster



PASSENGERS AND 2-MAN CREW fly in forward section of delta-shape supersonic transport. Passengers, in reclining chairs on either side of center aisle, sit on special cushions that automatically mold into form fitting rests. (Note seat fourth from rear.) Craft is air-conditioned to keep passenger areas at room temperature even though outer skin glows red hot.

would likely be covered with titanium skin insulated from the main structure. This design would protect the booster body from heat of its supersonic flight and the blast of the passenger transport rocket at launching.

FLIGHTS ECONOMICALLY PRACTICAL

Not only are supersonic flights technically feasible, but the airlines could make money on them, Bell Aerosystems engineers believe. They estimate the booster vehicle will cost about $15 million and the transport craft itself an additional $5 million. The booster should be good for 10,000 flights; the transport craft for 5000.

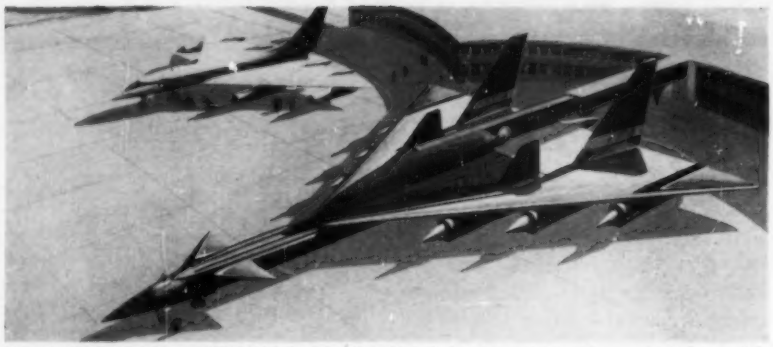
Operating costs between New York and Melbourne, the company estimates, would run about $23,250 each way. On this basis the airlines could profitably set their round-trip fares at $1550. Today, first-class round-trip jet fares to Australia run $1800 for a trip taking 38 hours.

As it stands now, flights under 4000 miles would be impractical for the vehicle. Trips for shorter distances in the 1980 period would most likely be made with Mach 3 supersonic aircraft such as the B-70 the engineers predict. But enough people are flying to cities more than 4000 mi away from the US to keep fleets of hypersonic transports busy. They would service such flights as New York to Berlin, Bombay, Buenos Aires, Cairo, Capetown, Honolulu, Melbourne, Rio de Janeiro, Singapore, Tokyo, etc. And flights from Chicago and San Francisco would tap even more cities.

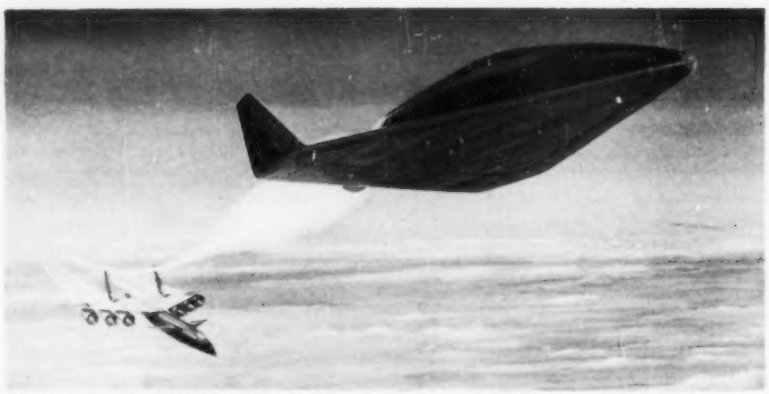
If the go-ahead signal were given today to develop such a craft it would cost an estimated $10 billion. However, by the time such a vehicle would be undertaken, say around 1970-1975, the bulk of the required R & D would already have been done.

The company today is working on many problems related to piggyback transport. It has contracts for the Air Force's B-70 program and for the Dynasoar program leading to a manned vehicle for short space flights. Both programs require study of leading-edge construction problems and the double-wall concept for glide reentry.

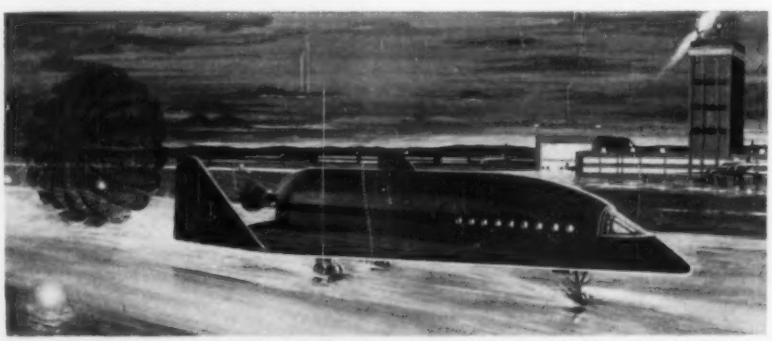
Concept of Bell's supersonic aircraft is primarily credited to Dr Walter R. Dornberger, a former general in the German army and now chief scientist for Bell Aerosystems. ■



NEW YORK AIR TERMINAL, 12 NOON: A booster aircraft capped by a 30-passenger transport is readied for supersonic flight. Takeoff of the booster and its piggy-back cargo occurs conventionally from a 10,000-ft runway (craft can actually be airborne in 5000 ft). The pair climb to an altitude of 20 mi, attaining a speed of 5300 mph, then booster returns to airport for next outgoing flight. Booster is envisioned as a thin dart-shaped craft, 200 ft long, and just thick enough to hold the JP fuel for its short flight. It has high, 150-ft swept-back wings supporting 6 turbo-ramjet engines, three to a side. Each engine develops 50,000-lb thrust at sea level.



ALTITUDE 20 MILES: Passenger transport separates from booster via rail tracks built on booster wing. Now powered by a gimbaled rocket engine burning an exotic fuel such as pentaborane or hydrazine, with nitrogen tetraoxide as oxidizer, transport accelerates to 15,000 mph and reaches altitude of 60 mi before the fuel burns out 4 min. later. From here, 400 mi from takeoff, the transport glides the remaining 10,000 mi to its destination. Its fuselage would be about 88 ft long. Inertial guidance provides automatic control for pilots during all stages of flight.



MELBOURNE, AUSTRALIA: 82 MINUTES AFTER TAKEOFF, transport lowers wheels and ejects a parachute to cut landing speeds to 200 mph. (Today's jets land at 140 mph.) It is also equipped with a turbojet in case pilot has to make one or more passes at runway. During landing, passengers are subjected to force of 1 g—somewhat less than the 3-g forces they experienced earlier during acceleration of the rocket. (Because of time belts, debarking passengers will find that Melbourne clocks read 4:22 a.m. of the following day.)

Japan Tries Automating Its Railroads

TOKYO—Japan's railroads, considered to be the world's most efficient, are moving toward automation. Hankyu, a privately owned interurban line centered at Japan's second largest city, Osaka, is now running four experimental units of four semiautomated electric cars on its lines.

Magnetic-amplifier controls permit setting for any speed and the speed will be maintained along straightaways, curves and 3% grades. Besides stepping up schedules, Hankyu engineers say sizable cost reductions are expected as braking is reduced, and when braking occurs the motor acts as a generator to feed power back to the line. Company engineers report the line is expected to switch to automatic-signal operating trains as soon as possible.

SUBWAYS TOO

Meanwhile, Hitachi—Japan's largest manufacturing company and second largest electronics producer and rolling-stock maker—has been operating an analog computer-controlled subway train in Nagoya. So far, experiments which began in October, 1960, have involved only a two-station operation and simulation of a passenger load with weights. Hitachi spokesmen say the route is a simple problem because there are no grade crossings—the bane of Japanese railroads.

—Sol Sanders, Tokyo News Bureau

Plastic Becomes Giant Exhaust

This 125-ft exhaust system will be used by a steel company to remove corrosive fumes from its zinc and tin plating lines. A ¼-in.-thick corrosion-resistant plastic sheet, calendered from a special compound and supplied by Seiberling Rubber Co's Plastics Div, comprises the manifold which ranges in dia from 22 in. to 42 in.

US Scientists Shrug Off Translations from USSR

WASHINGTON—The Commerce Department has quietly and sharply curtailed its Sputnik-inspired program of supplying English translations of Soviet scientific literature. PRODUCT ENGINEERING learns that the department has stopped issuing 100 separate publications which boiled down every article appearing in 100 Russian technical journals.

Partly to replace these, Commerce plans six new publications which will abstract only the "most significant" articles in Soviet and Chinese Communist magazines. Each of the six will cover a separate broad area.

Lack of public demand is blamed for cutting back the program established after the Soviets launched Sputnik I in 1957. There were widespread complaints at that time that American scientists weren't keeping abreast of developments from behind the Iron Curtain. John C. Green, director of the Department's Office of Technical Services, which operates the program, cites three reasons for the disinterest in translations of the 100 complete journals:

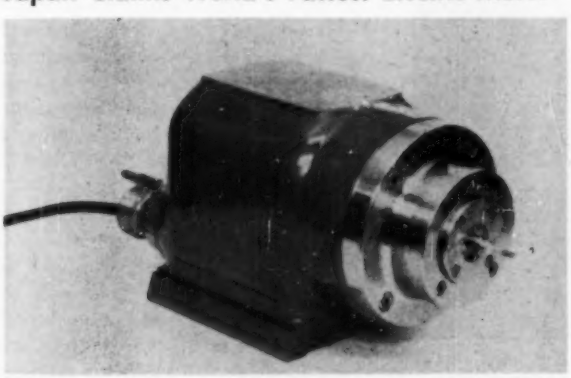
- US scientists apparently had a "mental block" against adding voluminous Soviet translations to their extensive diet of technical reading.
- The translations weren't tailored to the needs of the research scientist but were a byproduct of intelligence-gathering operations.
- The US government may not have given adequate promotion.

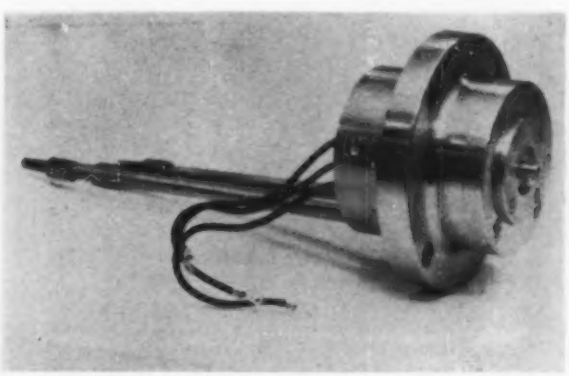
Green said that translations in the new series will be aimed more directly at the American scientist. ■

Want More Pay? Study Law

WASHINGTON—The Bureau of Labor Statistics has just completed an exhaustive study of salaries earned by various classes of corporate employes. Among professionals, the survey shows

Japan Claims World's Fastest Electric Motor





Toshiba, one of Japan's largest electrical manufacturers, has developed a 200-kw motor capable of 150,000 rpm and designed for use on lathes and grinders—especially when making bearings. According to Toshiba engineers, the new motor is similar in principle to other bi-polar, 3-phase induction motors, but its high speed is made possible by the high 3-phase, 2500-cycle frequency put out by a static inverter which has a silicon controlled rectifier. Motor is water-cooled, while compressed air sprays lubricating oil automatically. Next fastest electric motors are made by Mueller and Fortuna in West Germany (120,000 rpm); Fuji Electric (120,000 rpm) and Meidensha (130,000 rpm) in Japan; and Heald in the US (100,000 rpm) Toshiba engineers say.

that engineers average slightly higher than chemists and slightly lower than mathematicians. But as a whole, the technical people do poorly compared with lawyers, who topped the salary survey.

The survey covered about 1.1 million employes of whom 247,000 were engineers, working in companies with more than 100 employes. The data reflect salaries between January and June, 1960.

Engineers were divided into six groups depending upon responsibility. Inexperienced new grads, whose assignments are primarly routine (Group I) averaged $122 a week. Higher up the scale, those who performed work requiring originalty and judgment (Groug IV) averaged $189; and at the top, engineers who plan, coordinate and program several projects (Group V) averaged $272 weekly.

Mathematicians' salaries ranged from $111 for the employe who exercises little mathematical judgment to $289 for the supervisor who plans, coordinates and executes highly complex research. The chemists ranged from $106 to $263 a week.

Attorneys can command only $115 weekly, if inexperienced, but upon becoming general counsel or chief attorney for a company, they average $442 weekly. This is considerably above the $349 weekly grossed by directors of R&D.

About ⅔ of the surveyed companies who hire engineers will accept inexperienced college graduates. Most of these permit a range of entrance salaries, with the top earner getting about 10% above minimum. ■

Union of 17,000 Engineers Calls It Quits

WASHINGTON—Pres Russell Stevens of the American Federation of Technical Engineers last week threw his arms wide open in welcome to the 17,000 members of the independent Engineers and Scientists of America, about to be left homeless by the dissolution of their "professionals-only" union.

Joseph Amman, the Washington attorney who served as president and entire staff of ESA, decided to call it quits as of the first of the year because of financial difficulties and lack of interest on the part of engineers and scientists in a union of their own. He founded the organization in 1950.

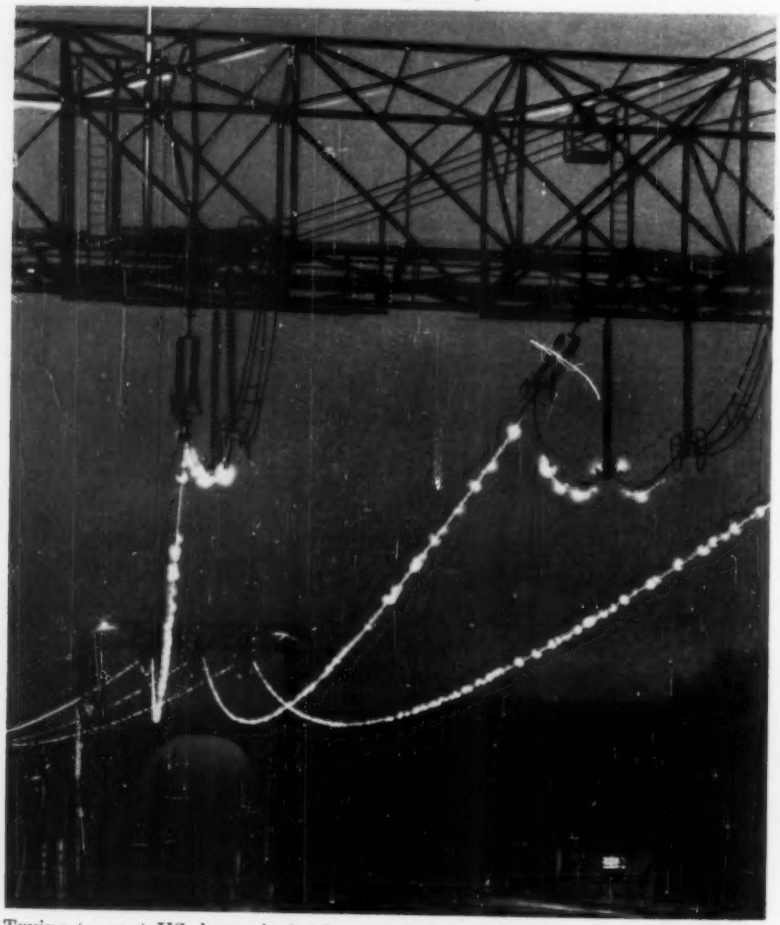
There always has been considerable opposition among professional engineers and scientists to unionism. Many protest their work is not compatible with the union movement. This feeling has grown even more widespread recently, with the rising status of engineers and scientists on the national scene.

The final blow to Amman's hopes apparently came last May when engineers at Western Electric voted to decertify the Council of Western Electric Professional Employes, local chapter of ESA. The union never recovered.

Several years ago, there were merger negotiations between Amman and AFTE, (the latter is the closest thing in the AFL-CIO to a professional union). This got as far as a meeting of the two executive boards in Dallas in April, 1956.

Stevens says AFTE will actively seek to affiliate the homeless locals or any of their members who wish to join the federation. But he will not be alone in this quest. Other unions which encompass engineers and scientists include the electrical workers, steelworkers, auto workers, and communications workers. The hitch is that none of these is an exclusively professional union, and that apparently is the kind of representation the remaining members of ESA want. ■

Even the Transmission Lines Light Up



Trying to meet US demands for increased power at economical rates, General Electric Co has energized the world's highest operating-voltage transmission system (460 to 750 kv). The 2-section, 4.3-mi. prototype system is located at the GE outdoor laboratory near Pittsfield, Mass, and is said to transmit 36 times as much power as a conventional 115,000-v line. Photo shows the corona that results when 750,000 v go through the three single conductors, which are set up to handle only 460,000 v. Conductors coming into the transmission tower from upper right give no corona because they're bundled in groups of four.

Some Ideas

for your file of practical information on drafting and reproduction from

KEUFFEL & ESSER CO.

Six years ago, K&E introduced the very first polyester-base drafting film—a special-purpose medium featuring extreme dimensional stability. Experience with that film indicated that a definite need also existed for a *general-purpose* drafting film, if one could be perfected. About two and a half years ago we succeeded, introducing HERCULENE® Drafting Film—the first polyester-base medium for general drafting to meet professional standards. Many recognized its value immediately, stocked up on HERCULENE, and have used it happily ever since. Others—a bit more "canny" about adopting a relatively untried medium—deferred decision, saying "see us in a year or so." Still others—having tried one or more of the other films marketed immediately after HERCULENE—seemed permanently disenchanted with *all* film based media. What with the passage of time and much favorable ado about drafting films in general, we rather think that those once stung may now have adopted a more congenial attitude—so we address ourselves solely:

To fence-sitters everywhere . . .

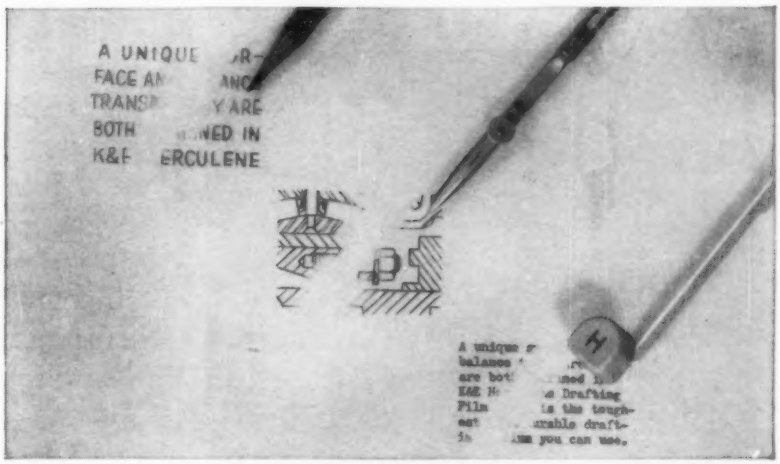
Just as we felt in '58, we feel today, that film has an important place in the drafting room. The only difference now is that experience has *proved* it so. Since 1958, the number of HERCULENE users has grown by leaps and bounds. All, we're happy to say, have found HERCULENE a welcome, efficient, and *much needed* addition to their stock of drafting media. It is these HERCULENE users who have written the record. Their many and rigorous tests, their months of experience, their numerous successes and continuing satisfaction are convincing evidence that HERCULENE is all we said it would be.

Why all the fuss about HERCULENE? . . .

HERCULENE combines practically all the qualities of a perfect drafting medium. An excellent product when introduced, it's even closer to perfection today. Working with major film users, K&E specialists have refined HERCULENE in many subtle ways since its introduction.

Unlike cloth or paper, HERCULENE is virtually indestructible. No matter how roughly or frequently a HERCULENE tracing is handled, it will never crack, wrinkle or fade. Absolutely waterproof, a HERCULENE drawing can never be permeated and ruined by moisture. Filed away, HERCULENE will last indefinitely. And HERCULENE has body, too, making it far easier to handle and file, and to keep flat on the drawing board.

Most of the refinements made in HERCULENE since 1958 have concerned its engineered drafting surface. HERCULENE's surface "take" for pencil, ink and typing is now better than ever. Erasability, of course, is excellent for all three. Contrast has been built up for sharper definition of line, too, yet all the transparency necessary for fast, clear reproductions has been maintained.



Two big bonuses, too . . .

A significant chapter in the HERCULENE story has been the development of a waterproof writing mate—the Duralar plastic pencil. Drawings made on HERCULENE with this waterproof pencil can actually be

washed in soap and water. Even gray, grimy "unreproducible" drawings can be washed spotless with this new technique. Many firms now use the HERCULENE/Duralar team exclusively . . . and are realizing undreamt-of savings in costly re-draws.

Some firms, of course, by virtue of smaller work volumes and "cleaner" or less frequent handling, will have little need for this new wash technique. Of particular interest here is another K&E exclusive recently introduced—the amazing Ruwe pencil. The Ruwe pencil will not withstand washing, but in every other respect, this new pencil is graphite-*plus*. Although of plastic composition, the Ruwe pencil has all the "fine" feel of graphite, erases well, and deposits a sharp, dense black line. The big bonus: Ruwe pencil lines are *virtually smudge-proof*. Rendered on HERCULENE's engineered drafting surface, they actually resist smudging better than graphite on regular paper!

We leave it to you . . .

The best test remains the one you make for yourself. We've just completed a new brochure, titled "A Report on the Growing Acceptance of Polyester Film." In it is detailed most of what we have learned about HERCULENE and its use since 1958—including tests you can make to assess its every property. We'd like you to have a copy of this new brochure—plus a sample sheet of HERCULENE, a Duralar pencil, and a Ruwe pencil—for your own private testing. To get these free samples, simply fill out and mail the coupon below:

KEUFFEL & ESSER CO., Dept PE-1, Hoboken, N. J.

Gentlemen:

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POINTS OF VIEW

THE QUESTION:

What Program Does the

Since 1926, Dr Augustus B. Kinzel has been with Union Carbide. He started as a research metallurgist; today he is vice-president in charge of research, a position he has held for the past five years. Besides being president of the Engineering Joint Council, he holds a position with the National Academy of Sciences. He has conducted research projects on titanium, stainless steel, structural alloys and ferroalloys. At Union Carbide he has done work on industrial gases, applied machanics and atomic energy, among many others. Previously, he worked with the General Electric Co and Henry Disston and Sons Inc. He has more than 40 patents to his credit. His degrees include a BA from Columbia in 1919, BS in engineering from MIT in 1921, doctorate from the University of Nancy in France and two honorary doctorates.

Enrollment in engineering schools is declining; engineering societies are hampered by disunity; some scientists feel there should be a federal Department of Science and Engineering. The Engineering Joint Council, which represents engineering societies at the national level, is concerned with these and related problems. Here are the views of its president, Dr Augustus B. Kinzel.

First, let us understand the purpose of Engineers Joint Council (EJC). Its function is to extend the contribution of engineering to society through the cooperative marshaling of the resources and creative abilities of the engineering fraternity. The fields of engineering overlap, and a place is needed where the members of each can gather, discuss and study jointly. EJC provides a forum for the engineering societies, and a means to resolve their common questions and problems.

A significant concern of EJC has been the development, education and utilization of engineers. In this area, the Engineering Manpower Commission is the principal agent of EJC. Its objective has been to ensure proper utilization of engineers in both the Armed Services and in industrial employment, and to obtain recognition of engineering employment in essential civilian activities. As a step in this direction, EMC has maintained a constant evaluation of trends in engineering enrollment, demand and salaries. While these data have kept the profession and the individual informed on significant factors affecting engineering manpower, and have helped to equip the engineer to deal more effectively with his employment environment, they had not provided an over-all evaluation of engineering brainpower resources.

On behalf of the National Science Foundation, EJC has completed a study on the feasibility and desirability of creating a national engineers register to list all engineers in the country. Such a listing would serve as a tool for mobilizing engineering talent. But, we concluded that such a register would cost too much and be too difficult to maintain. Instead it is expected that EJC will update and expand—in critical areas—its present register, in which a selected sampling of engineers represents the profession with regard to mobilization. In addition, as a joint project with the Engineers' Council for Professional Development, a comprehensive survey will be initiated to develop realistic information on the national characteristics of the engineering profession to assist the educational institutions and learned societies in developing sound program criteria.

EJC Want for Today's Engineers?

Engineering unity

With regard to the entire question of the status of the profession, EJC believes that one of the most effective means of preserving the dignity and prestige of engineering is to enable engineers to make united and instructive contributions to the grave technological problems of our society. In this context EJC, in cooperation with the Engineering Foundation, is launching a study to determine the advisability of creating a National Academy of Engineering, either as an independent organization or as major component of the National Academy of Sciences. Such an academy could present a truly united voice of engineering technology and set national standards for engineers and engineering achievements, which now are fractionalized and diversified.

And while we are on the subject of unity, unity is needed not only for the purpose of presenting a single professional voice, but also because uncoordinated technical activities can be detrimental to the nation. Since the first Sputnik was launched the government has become aware of the importance of engineers and scientists, yet most government technical activity remains uncoordinated. To aid in matters of science and engineering, there is only an advisory board that makes recommendations to the President. It has been very useful, but this usefulness is a direct function of the amount of backing it gets from the White House. Cooperation among government agencies involved in scientific or engineering projects is strictly voluntary, and depends exclusively on the goodwill of the people involved. Each agency chief reports directly to the President; this is very poor organization.

The dilemma could be solved by creating a Department of Engineering and Science. The various scientific and engineering efforts going on in the many government bureaus and agencies could be integrated if there were a single department to which all could report. The new department would not take over the work of any agency, but would define the areas and roles of the many now uncoordinated groups. The big difference between the proposed agency and the present advisory board would be power—power to act.

Of course, this would be a very complex operation, and would take a lot of advance preparation. At a recent congressional hearing, I recommended that a commission, similar to the Hoover Commission, be established. With both technology and government represented, this body would investigate the various agencies to determine which would come under the control of the new department. There have been some doubts that one person or group could speak for the many fields of science and engineering. Engineers and scientists have very diverse views on many issues, and a single policy for all would be difficult to find, but it would not be impossible. There are a number of good men available who can speak with competence for both sides. A continuous spectrum must exist—from the scientist, who is concerned chiefly with basic knowledge, to the engineer, who must apply that knowledge.

Engineer in society

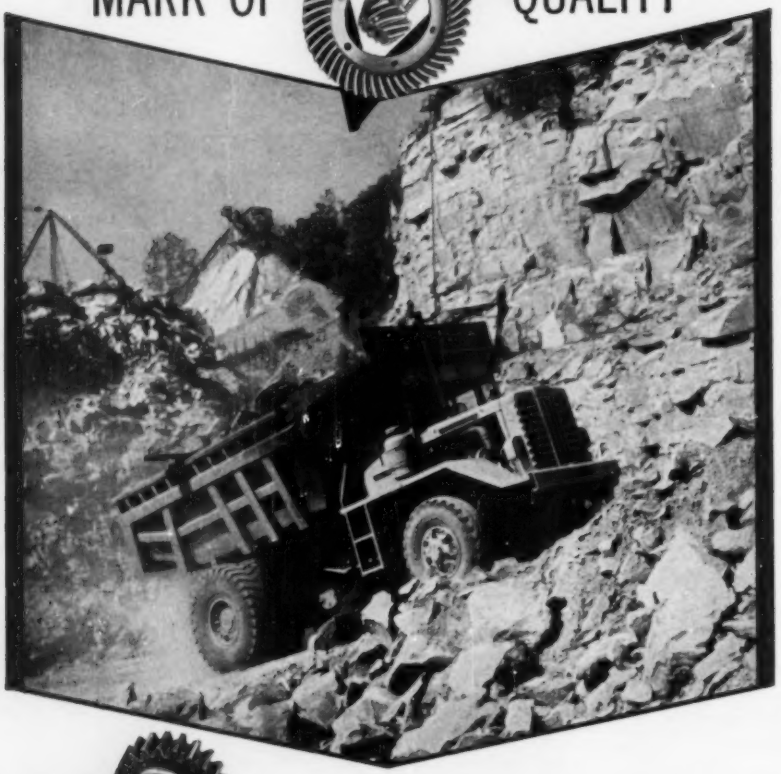
In addition to answering immediate technological needs, EJC is also concerned with identifying the significant problems that will confront our society in the next two decades, and in determining how engineering can help solve them. The Engineering Research Committee, composed of distinguished engineers, scientists and others, is developing this theme. Its extensive documentation will serve as a guide for educational institutions, engineering societies, industry and other sectors of the economy for achieving cooperation in advancing engineering capabilities and accomplishments.

Since the fundamental purpose of EJC is to encourage concerted and coordinated attention to problems basic to engineering technology, the hard core of its activities must be oriented to provide leadership in areas of interdisciplinary interests. EJC now has underway several programs oriented toward this objective:

Engineering literature—the rapidly increasing amount of technical information has made it impossible for engineers to keep up to date on all phases of interest, and the volume and translation problems of foreign literature limit acquaintance with significant new developments abroad. These problems are being studied by EJC in an effort to develop programs to identify the important foreign literature and ensure its early translation and prompt dissemination to the engineer. The problems of abstracting, and indexing and providing an adequate information-retrieval system are also receiving attention.

Coordination of technical activities—there already exists a considerable amount of intersociety cooperation in technical problems and meetings. The function of EJC is to identify new areas for interdisciplinary action to forestall unnecessary specialty splintering and to develop more effective integrated programs. Specific examples already exist, such as the Nuclear Congress, wherein the interests of over 20 societies in the nuclear field are coordinated in one major meeting. But even here, further integration is desirable. The widespread use of information-processing systems has resulted in the establishment of an intersociety committee to exchange data on the application and utilization of these systems in the many engineering specialties. Beyond these examples, the development of integrated engineering systems has generated engineering interest in a wider spectrum of specialties and has accentuated the need for the engineer's participation in technical activities and progress in fields other than that of his principal specialty.

MARK OF QUALITY



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Fairfield's facilities are unexcelled — you get all the benefits of high production rates and big volume output in an ultra-modern plant designed for producing fine gears EFFICIENTLY . . . ECONOMICALLY. Your inquiry will receive prompt attention. FAIRFIELD MANUFACTURING CO., INC., 2305 S. Concord Rd., Lafayette, Indiana.

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READER TO EDITOR

Placing the Decimal

To the Editor:

In your article "Better Way to Place Sliderule Decimal Point," Oct 10, p 65, there must be many ways of figuring placement of the decimal point in sliderule work —and the author's is about as good as any. However, to avoid all these "soups" and "subs", here's a home-grown method which works without fail. At least for us.

First, move all decimal points so that numbers are more than 1, but less than 10. Keep track of the decimal shift by putting 0's in the numerator, if decimal is moved to the left; 0's in the denominator, if moved to the right. An example makes this much easier to understand.

Problem:

30.78 x 400.3 x 0.006/0.0032 x 10012.6

Reduction of numerator: 3.078 x 4.003 x 6 0 x 00/000
a b c a b c

Reduction of denominator: 3.2 x 1.00126 0000/000
d e e d

(Letters indicate from which figure corresponding 0's come)

Now, we have a simple problem— approximately 3 x 4 x 6/3 x 1 which is roughly 24.0

When we combine all the zeros, we have $\frac{0 \times 00/000}{0000/000}$

Canceling leaves a net of one zero in the denominator. In other words, 10^{-1}. Thus, final answer should be close to 2.4, QED.

The basic approach is very similar to your article, but seems less cumbersome to work. *Chacun à son gout.*

—Lucien R Greif
Greif Associates
NYC

Isometric Projection

To the Editor:

In the Nov 21, 1960, issue of Product Engineering is a very interesting article describing a new system for the isometric projection of orthographic views.

This system has been studied with some care in our drawing office and is considered to be a real advance on present methods.

However, is it possible that an error has been made in the description of the "quadrangle"? It appears from our calculations that the side bounded by angles 150° and 105° should be 0.2988X rather than 0.3002X.

We would appreciate having this clarified. —C B Meyers
St Lawrence Seaway Authority
Montreal

To the Editor:

Yes, indeed, the .3002X is not correct. According to my calculations—done for the first time last night—the figure should be 0.298,858,6 when using square root of 2 = 1.414,214 and square root of 3 =

1.732,051. Therefore, to four places, the correct answer would seem to be 0.2989, or to three places 0.299, not 0.300.

Fortunately, in the patent description, this figure was not used. Point *B* of the quadrangle moves along a line at ⅓ of the distance from one side of the equilateral triangular frame to the opposite apex. This, with the exact angles of the quadrangle, completely describes the instrument's geometry.

I have always laid out the instrument's geometry with beam-compass and straightedge, at a scale much larger than required for the instrument, then cut down to the size being made. Theoretically, at least, the graphical solution is exact.

Mr Booker inserted the figure and the factor 0.3002 in his paper, which is the first time that such a factor was published or calculated. This does not excuse me for not checking it, however, in the interval of the days between his publication and the time when the copy for PRODUCT ENGINEERING was checked. I am afraid that I accepted it as correct, unquestioningly.

I appreciate very much the alertness and kindness of Mr Meyers in calling attention to this error.

—WAYNE L SHICK
Professor in General Engineering
University of Illinois

COMING EVENTS

JANUARY

9-11 . . . . Institute of Radio Engineers jointly with AIEE, ASQC & EIA, 7th National Symposium on Reliability and Quality Control, Bellevue-Stratford Hotel, Philadelphia

9-13 . . . . Society of Automotive Engineers, International Congress & Exposition, Cobb Hall, Detroit

16-19 . . . . Instrument Society of America, Winter Conference & Exhibit, St. Louis

29-Feb. 3 . . . . American Institute of Electrical Engineers, Winter General Conference, NYC

FEBRUARY

1-3 . . . . Institute of Radio Engineers, Winter Convention on Military Electronics, Biltmore Hotel, Los Angeles

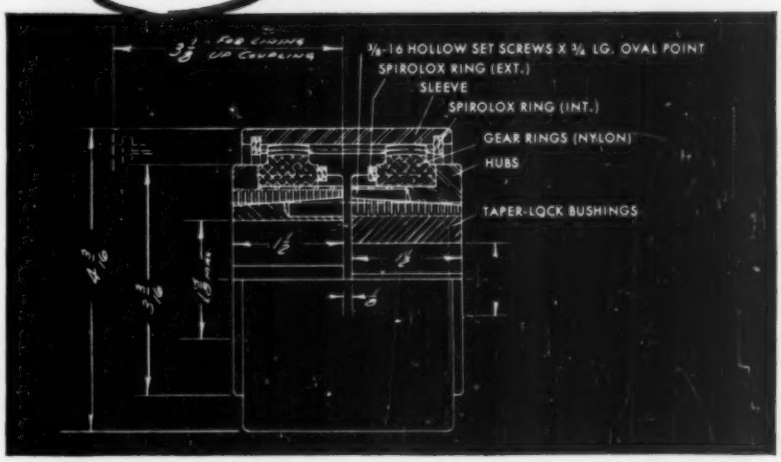
7-9 . . . . Society of the Plastics Industry, 16th Annual Technical & Management Conference, Edgewater Beach Hotel, Chicago

15-16 . . . . Institute of Radio Engineers, American Institute of Electrical Engineers, 8th Annual International Solid-State Circuits Conference, Univ of Pennsylvania & Sheraton Hotel, Philadelphia

For a current listing of addresses of societies and associations send 25¢ to PRODUCT ENGINEERING Reader Service Dept, 330 W 42nd St, NY 36. Ask for brochure R32.

design facts . . . on

WALDRON
Series "M"
Couplings

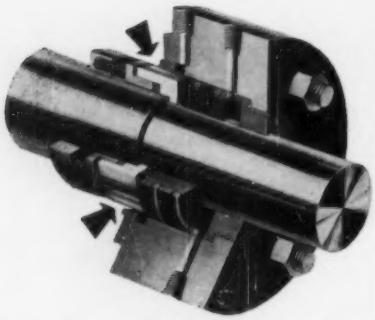


The new Series M couplings—with nylon gears and steel sleeves—need no lubrication. Equipped with Taper-Lock bushings—each coupling size can accommodate a range of shaft sizes. For instance, the 162M, now available, will take shafts from ½" to 1⅝" with proper size Taper-Lock bushings, and up to 2" without the bushings. Hubs are machined from bar stock and the one piece sleeve is made of steel. This design means a smaller, light weight coupling that is easier to install and maintain and yet can transmit the necessary power. Size 162, Series M gear couplings can be used for continuous operation up to 5000 rpm at torques up to approximately 2000 inch pounds.

WRITE FOR CATALOG

WALDRON Couplings

WALDRON-HARTIG DIVISION
MIDLAND-ROSS CORPORATION
BOX 791, NEW BRUNSWICK, N. J.



Dura Seal Type PTO Balanced Seal with location of Kennametal* Seal Ring indicated by arrows.

It's tough to seal ethylene . . . but it can be done with KENNAMETAL

Single mechanical seals for ethylene and other light hydrocarbons must operate for several minutes at a time in vapor, without benefit of liquid lubrication. The seal and mating faces must therefore be able to operate virtually dry during these periods, at pressures up to 600 p.s.i., without damage to the seal faces.

For this difficult sealing job, Durametallic Corporation has found Kennametal Seal Rings superior to either cast alloy or ceramic rings. Kennametal carbide rings can operate successfully with a minimum of lubrication. They stand the additional loading imposed by these adverse conditions, provide stability under high temperatures, and resist thermal shock.

Specify Kennametal for exceptionally good dimensional stability, for successful sealing of a great variety of media, for strength without great mass, for corrosion and wear resistance, and for high temperature applications. Kennametal Inc. makes seal *rings* used by leading manufacturers of seals.

Send for these booklets: B-111-B —"Properties of Kennametal" and B-666—"Proven Uses of Kennametal and Kentanium.*" Write Dept. PE, KENNAMETAL INC., Latrobe, Pennsylvania.

*Kennametal is the registered trademark of a series of hard carbide alloys of tungsten, tungsten-titanium, and tantalum. Kentanium is the registered trademark for one of the series that has special advantages for applications requiring a lighter weight material and/or exceptional stability at temperature extremes. 33548

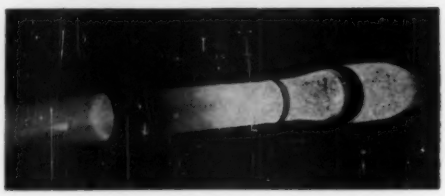
INDUSTRY AND KENNAMETAL ...Partners in Progress

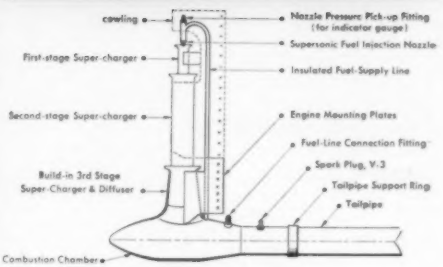
FOR YOUR INFORMATION (personal)

And then you whirl away—for $248

For just $248 ($540 a pair) you can now buy yourself a wingtip jet engine and take off for parts unknown. The engine, fueled by liquid propane, is a true pressure jet, designed for helicopters (see photo), and has "sonic-synchronized" burner intake that permits the engine to operate statically, producing 90% of its maximum thrust, as well as dynamically, by means of a simple pushbutton device. Gluhareff Helicopter Corp, which makes it, says the engine has a life expectancy of well over 1000 hr, weighs just 5 lb, including nozzles and lines.

P.S. If you'd like just the blueprints, they're $8 a set for the engine itself, $8 for the blade assembly and details; $4 for the fairing blade tip.





BABY JET construction is outlined above. Top photo shows a typical application (you stand on the platform, hold the rail, and take off). Center picture shows engine test.

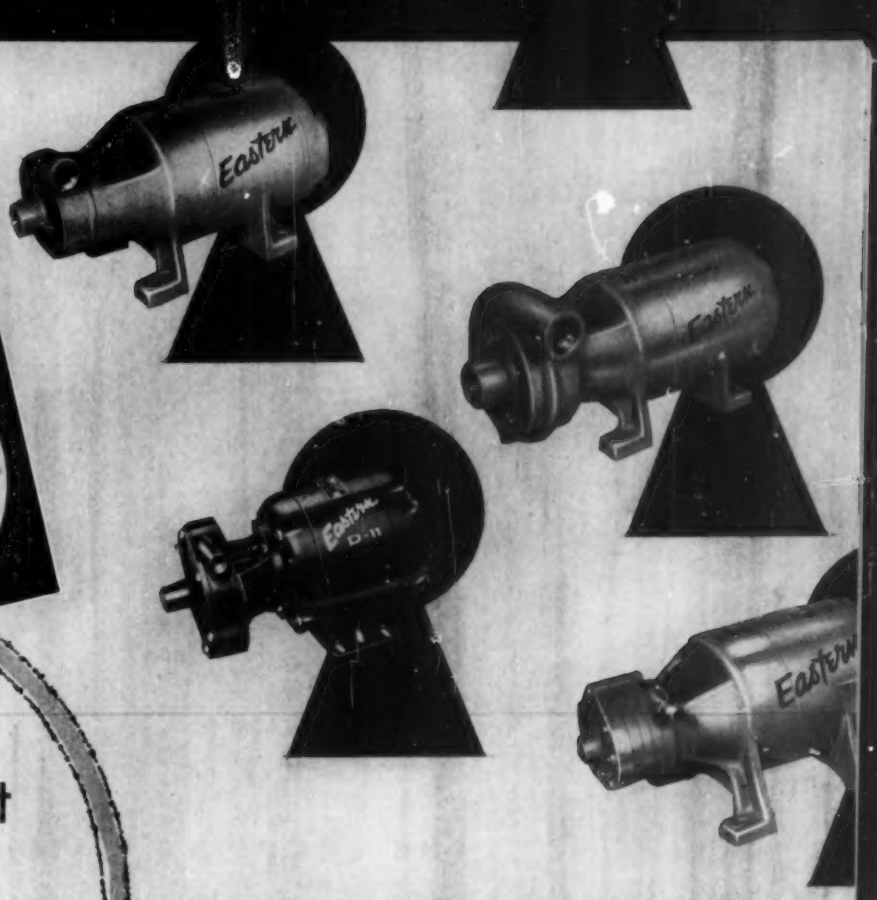
How to get it—cheap—from Uncle Sam

As of Jan 1, there's an entirely new procedure for military surplus property sales, and a new booklet (15¢ from the Government Printing Office) to tell you how to buy anything from an LST ($61,000) to a used typewriter ($10 up)—and you can buy one or a quantity. Application (order) forms will soon be available at military installations throughout the US. Fill one out, and you'll automatically be informed of sales of the type in which you're interested in any area of the country you specify. There'll even be closed-circuit TV shows so you can see what's available in other parts of the country. Toughest part of the whole thing: addressing the application-form envelope to the central agency. Its name is: Armed Forces Surplus Property Bidders Registration and Sales Information Office. Location as yet unspecified; but it will be under supervision of the Asst Sec Defense, Supply and Logistics, Washington, DC.

British accent answers your phone

The "first all-British automatic telephone answering and recording machine" is proudly announced by Southern Instruments Ltd of Surrey. Another of the company's new "Birthday Products" (*PE*—Dec 5 '60, p 6), it will say "hello," give a pre-recorded message, and accept a reply. Capacity: "equivalent to 80 pages of single-spaced typing at normal speech rates" (about an hour's talk). Name: Ansafone. —ARG

Eastern



your key to the perfect choice of CENTRIFUGAL PUMPS

A new catalog opens wide the doors to designers of process equipment — tells all you need to know in terms of engineering data, performance charts, seals, metals, mountings!

If you need centrifugal pumps with these characteristics, this reference book is for you:

- PRESSURES: to 21 psi in single stage pumps; to 70 psi in multi-stage types.
- FLOWS: capacities to 70 gpm in single-stage pumps, to 10 gpm for multi-stage models.
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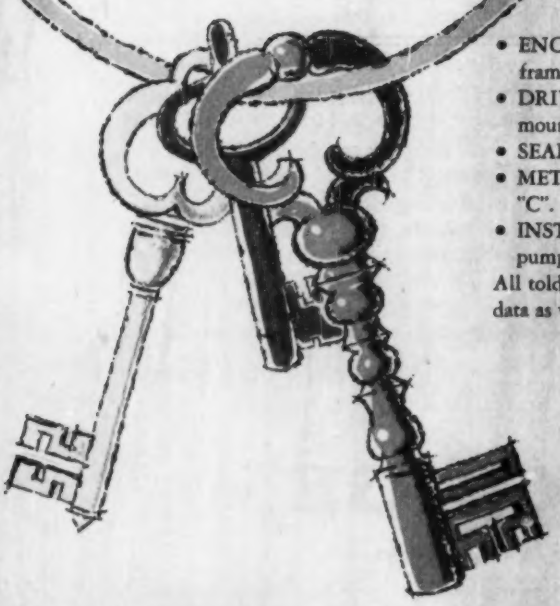
- ENCLOSURES: drip-proof, totally enclosed, and explosion-proof ballbearing frames.
- DRIVES: Space-saving close coupled pumps most rugged and popular. Pedestal mounted arrangement without motor available as alternate for belt or coupling drive.
- SEALS: a variety of rotary seals and stuffing boxes, to fit every application.
- METALS: your option of cast iron, bronze, stainless steel, Monel, Cast Iron, Hastelloy "C".
- INSTALLATIONS: a wide range of transfer, recirculation, feed, boost and filter-pumping applications.

All told, 50 different models are described in full — and you get a wealth of technical data as well. Write for new catalog 130 now!



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EASTERN INDUSTRIES, INCORPORATED

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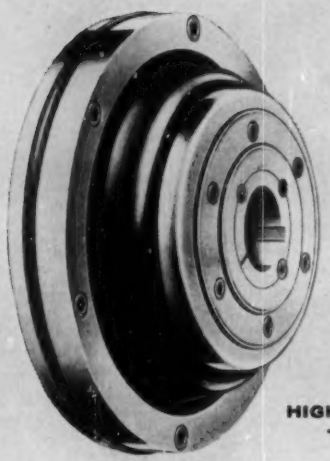
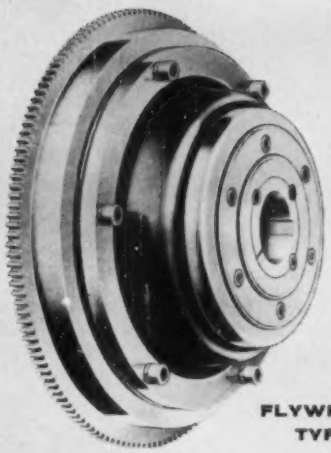


HIGH SPEED TYPE

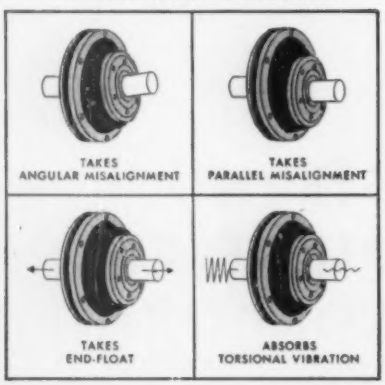


FLYWHEEL TYPE

NOW! THE COUPLING WITH THE 4-WAY FLEX IN TWO NEW TYPES — HIGH SPEED AND FLYWHEEL

STANDARD TYPE

THE 4-WAY FLEX OF PARA-FLEX



DODGE **Para-flex**

Industry asked for this—and here it is! Dodge Para-flex, the unique coupling that swallows up misalignment, is now available for high speed applications, and for high torque at either high or low speed.

The new Dodge High Speed Para-flex is specially designed for operation with motors and internal combustion engines that turn up to 5230 rpm.

The new Flywheel Para-flex, with the same capabilities, has a flexing element that bolts directly to the flywheel of internal combustion engines.

Like the Standard Type (with capacities up to 2000 hp at 1080 rpm) these new Para-flex Couplings feature a modern, tire-like flexing element that handles angular and parallel misalignment, end-float (or any combination) and absorbs torsional vibration. The amazing performance of Para-flex Couplings is a matter of record in thousands of installations.

Ask your Dodge Distributor—or write us for new technical bulletin.

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CALL THE TRANSMISSIONEER—your local Dodge Distributor. Factory trained by Dodge, he can give you valuable help on new, cost-saving methods. Look under "Dodge Transmissioneer" in the *white* pages of your telephone directory, or in the yellow pages under "Power Transmission Equipment."

PRODUCT ENGINEERING HORIZONS

January 2, 1961

THE CREATIVE CATERPILLAR

There is in France a race of caterpillars which has a very specialized way of finding food. When a colony gets hungry, its members line up, each hooking his tentacles into the tail of the caterpillar ahead. And off they go, the lead caterpillar doing the searching and guiding. The rest just follow the leader.

Once there was a zoologist who wondered about this caterpillar chain. Was the leader smarter, a better food-finder, was there a "pecking order" —or was the leader just the caterpillar who happened to be in front when the trek for food began? The zoologist worked a chain into a circle and got the lead caterpillar lined up with the tail-end one. The "leader" promptly hooked on, and the chain started to go round and round. Not until a week later, when one caterpillar died of hunger and broke the circle, did the chain begin to cover ground again.

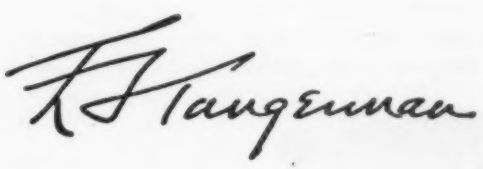
Imagine how a creative caterpillar would upset this colony! What if he were to come up with the idea that each caterpillar strike out on his own? Imagine the pressures to get him back into line! First the other caterpillars: "Why are you doing this to us?" "Don't you like to eat regularly?" "What's the matter with things as they are?" "What was good enough for Grandpa is good enough for us." "So you think you know more than the caterpillar council." "Your idea is no good, or some other caterpillar would have thought of it long ago."

Then the lead caterpillar: "What are you trying to do, show me up?" "Is this loyalty?" "After all I've done for you, you do this to me!" "Why don't you just forget the whole thing—or don't you like it here?"

They can certainly make a creative caterpillar feel like a worm. And if he tries to turn, as rebellious worms do, obstacles will be put in his way. Nobody will know the proper procedure, the papers will be missing, there will be dark warnings of banishment—they may even threaten to feed him to the birds, because his ideas are for the birds anyhow.

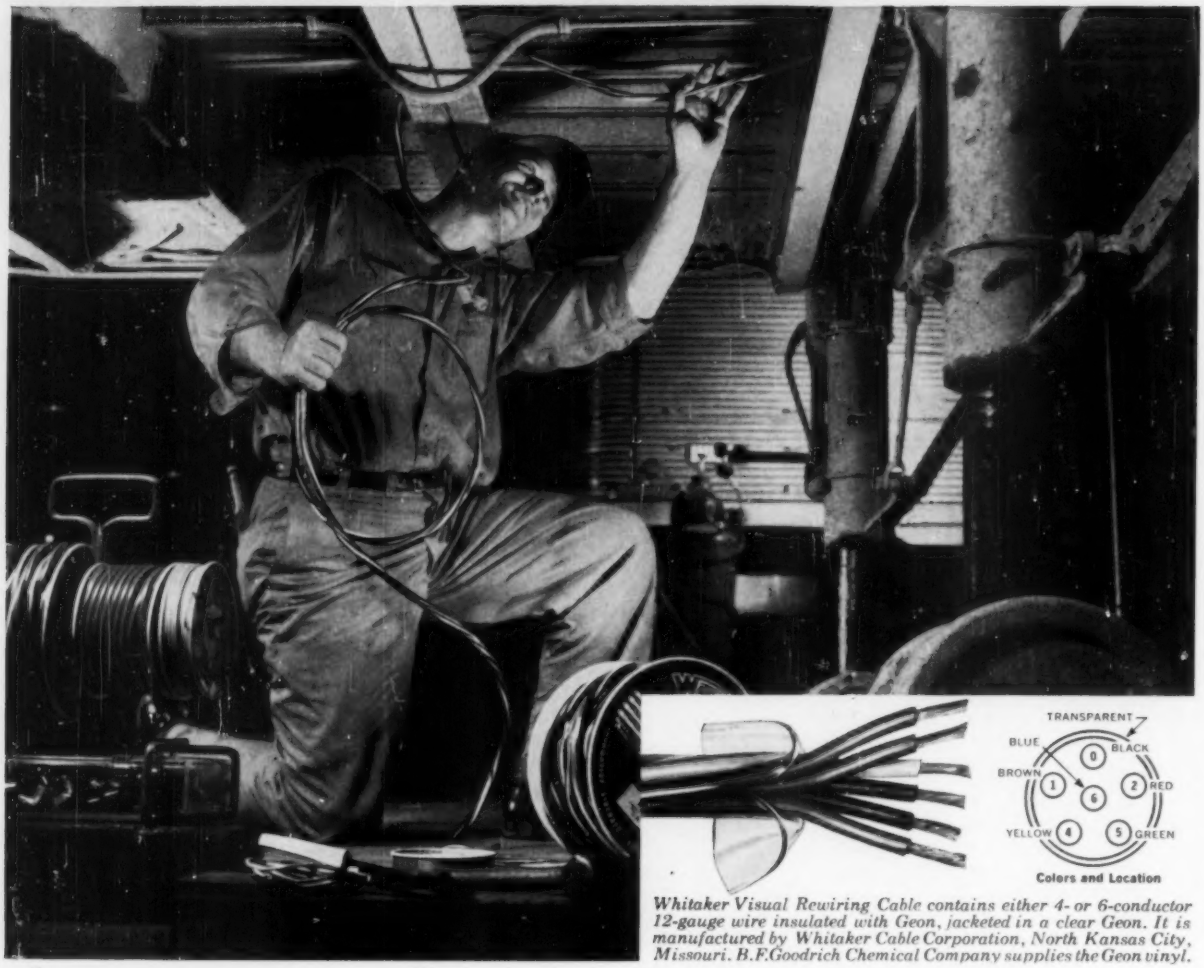
But let's say he keeps right on turning—and begins to get somewhere. The whole colony will promptly clamp onto his tail, applying another traditional philosophy of "all for one and one for all." They may even get him to sign a patent release to make sure he doesn't just take off on his own. And they'll hang back, letting him not only lead but also drag them along as well, mentally as well as physically.

Moral: **If you break the chain, what happens to you is your own fault. A light in your eye will only attract the birds.**



Another new development using

B.F.Goodrich Chemical *raw materials*



Whitaker Visual Rewiring Cable contains either 4- or 6-conductor 12-gauge wire insulated with Geon, jacketed in a clear Geon. It is manufactured by Whitaker Cable Corporation, North Kansas City, Missouri. B.F.Goodrich Chemical Company supplies the Geon vinyl.

Transparent cable jacket of Geon gives truckers see-through convenience

Designed to meet new ICC truck-trailer wiring requirements that call for higher-capacity electrical circuits, this new cable gives installers real convenience. Conductors insulated in various colors of Geon are contained in a jacket of clear Geon vinyl, so that locating wires for making connections is fast and easy.

At the same time, truckers get top quality electrical protection because Geon gives excellent dielectric properties and good resistance to abrasion, weathering and heat. It is non-flammable, has low temperature flexibility and is extremely inert to oil, chemicals and solvents. Geon retains its properties over years of service.

Here's another example of the way Geon vinyl improves products. For information, write Dept. NO-1, B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

Geon VINYLS

B.F.Goodrich Chemical Company
a division of The B.F.Goodrich Company

B.F.Goodrich

GEON vinyls • HYCAR rubber and latex • GOOD-RITE chemicals and plasticizers

MECHANISMS–
a 9-step refresher course

It's too easy to forget what you know, to lose the easy familiarity with the basic ideas from which our handbook formulas were derived. German engineers, like American ones, have learned that knowledge can thus become rusty. So the Verein Deutscher Ingenieure (VDI), in collaboration with the Chamber of Commerce and Industry of Brunswick, sponsored a refresher course in mechanisms there last year. We've selected nine of the 20 lectures by 15 authors as of most interest to you, edited them into concise presentations, and will publish them weekly, starting with the current instalment. Publication is approved by VDI-Verlag GmBH, Duesseldorf. Dr. F. R. Erskine Crossley of Yale University School of Engineering brought the series to our attention, and supervised the translation and editing.

Six of the lectures are by Prof. Kurt Hain, who directed the project for the Division of Mechanism Theory, VDI; three are by H. Schaedler and G. Marx. All three men are on the staff of the Institute for Fundamental Research. Prof. Hain will include these lectures in a course presented early this year as visiting professor of Mechanical Engineering at Yale.

The nine will be available as a combined reprint for $1 after the series is complete. Address Reader Service Dept., Product Engineering, 330 W. 42nd St., New York 36.

turn page for first instalment...

SPRING MECHANISMS–force analysis ▶

nine lectures on
MECHANISMS

1...SPRING MECHANISMS—force analysis
2...SPRING MECHANISMS—point balancing
3...SPRING MECHANISMS—continuous balancing
4...POWER CYLINDER MECHANISMS—full stroke
5...POWER CYLINDER MECHANISMS—intermediate positions
6...FEEDER MECHANISMS—types
7...FEEDER MECHANISMS—applications
8...FEEDER MECHANISMS—angular motions
9...FEEDER MECHANISMS—curvilinear motions

1. SPRING MECHANISMS— force analysis

KURT HAIN
Institute for Fundamental Research
Brunswick, Germany

Mechanism proportions must be coordinated with choice of spring dimensions. Here are graphical methods that will simplify the solutions.

Consider an extension spring. We know that when the position of load varies, its moment about a pivot point changes accordingly, and the problem is to find a spring to produce an equal and opposite balancing moment. The energy stored in the spring must be equal to the energy released by the sinking load in order to balance the load at every intermediate position. In general, it can be assumed that the spring-rate curve is a straight line.

To balance load moment

Take the case in Fig 1 of an extension spring designed to balance the moment Wv of a given load in a particular position. It does this with an equal and opposite moment:

$$Wv = m_F = Ph = rbc \sin \phi \left(1 - \frac{a}{\sqrt{r^2 + b^2 - 2rb \cos \phi}}\right)$$

where the balancing moment varies with the angle ϕ, while all other factors are constant. Many different springs can be designed for the spring rate c, by varying the dimensions D, d, and n in the usual spring-rate equation:

$$c = \frac{P}{f} = \frac{Gd^4}{8D^3n}$$

This approach divides the problem into two parts:

- Design a mechanism for the required variable moment, assuming an arbitrary spring constant c.
- Find the spring dimensions for the chosen spring constant.

However, in designing the mechanism the two parts of the problem need to be coordinated. To do this, consider those spring factors which will affect dimensions of the mechanisms. For example, the elongation f required from the spring will be limited by the allowable shear stress given in the usual equation:

$$S = \frac{k8DP}{\pi d^3} = \frac{kGdf}{\pi D^2 n}$$

Here, the k factor compensates for increase in stress as ratio D/d decreases:

D/d	26	20	10	9	8	7	6	5
k	1.05	1.06	1.14	1.15	1.17	1.20	1.24	1.28

Next we assume over-all spring dimensions and calculate the probable spring rate needed. If $d = \frac{5}{16}$ in., $D = 2\frac{1}{2}$ in., $n = 40$, and $a = 16$ in., the spring rate is

$$c = \frac{Gd^4}{8nD^3} = \frac{11{,}500{,}000 \times (5/16)^4}{8 \times 40 \times (2\frac{1}{2})^3} = 22.2 \text{ lb/in.}$$

If a limiting stress of 70,000 psi is chosen the maximum deflection is:

$$f_{max} = \frac{70{,}000 \times \pi \times (2\frac{1}{2})^2 \times 40}{1.17 \times 11{,}500{,}000 \times 5/16} = 13.09 \text{ in.}$$

This spring can be used with the lever arm in Fig 2(A) where minimum deflection of the spring is represented by position A_1 and maximum by A_2. Length $A_2M = a + f_{max}$ where f_{max} is determined above. Force P_1 can be calculated from the equation for spring rate c, or it can be found from a spring-rate curve, Fig 2(B). Shaded area under the curve is the amount of work between the two points, assuming negligible friction.

Space limitations on loading the pivot bearing may make it desirable to balance a given load with two springs, Fig 3(A). The second spring F_2 can produce the same balancing effect in other positions, such as F_2', assuming negligible friction. Or both springs can be replaced by a single spring, Fig 3 (B), whose resultant moment is the algebraic sum of the individual spring moments.

Springs with a pulley

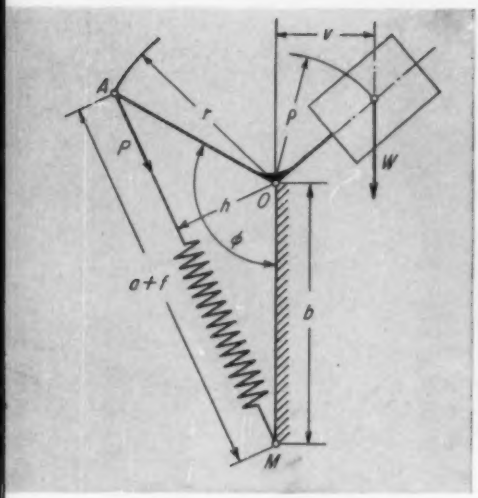
Another way to balance a load having a moment about a given point is shown in Fig 4. Here a spring applies tension to a rope anchored at M and wrapped around a swinging pulley. The force P_1 for any elongation of the spring is equal to the opposing force P_2, assuming negligible friction, and their resultant is P. The moment of the spring force is $m_F = Ph$, or in terms of the individual forces:

$$m_F = P_1h_1 + P_2h_2 = P_1(h_1 + h_2)$$

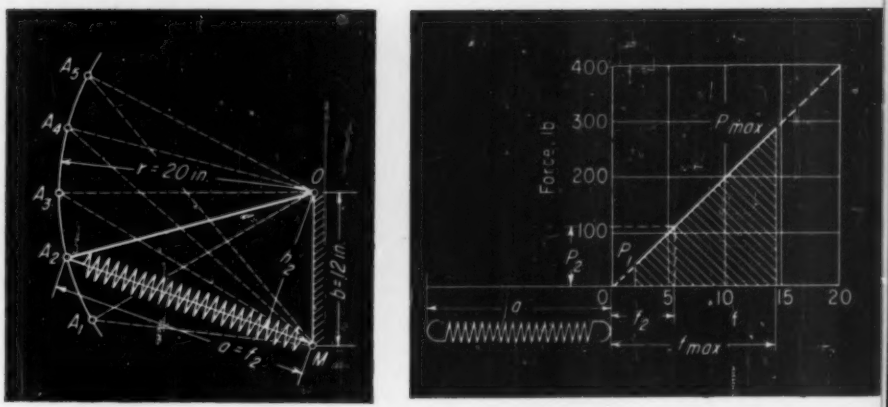
A variation of this could include a spring on each side of the pulley. For two such springs connected in series, with spring rates of c_1 and c_2, the resultant spring rate c is:

$$\frac{1}{c} = \frac{1}{c_1} + \frac{1}{c_2}$$

Either one or two springs can be used, depending on the



1 — SPRING ATTACHED TO LEVER ARM is one of the simplest mechanisms for balancing load.



A B

2—SELECTION OF LEVER-ARM LENGTHS (A) has to be coordinated with the required spring rate (B) in order to balance the load moments at each point.

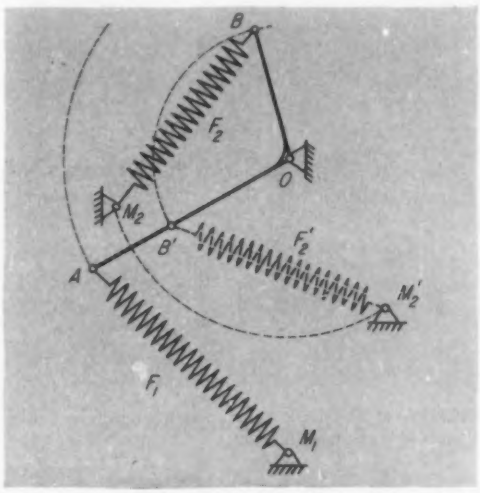
situation, to produce the needed balancing moments about the pivot point. Balancing moments for each position of the pulley can be determined by the graphical methods shown in Fig 5. The pulley is assumed fixed, with points M and N forming involute curves e_M and e_N as the rope unwinds about the pulley. Starting at tangent points U and X, the pulley circle is divided into a series of small segments with the arc lengths measured off on the tangents so that $UU_1 = UT_1$, $U_1U_2 = T_1T_2$, and $XX_1 = XY_1$, $X_1X_2 = Y_1Y_2$, etc. Next, draw circular arcs about U and X with UM and XN as radii; similar arcs are then drawn about U_1, U_2, U_3 and X_1, X_2, X_3 to form the involutes e_M and e_N.

Now swing lever arm OA through some angle ϕ_n into position OA_n. Then using A as a center and A_nM as a radius, draw an arc to cut involute e_M at M_n, and another arc from center A with AO as radius; a third arc is then drawn from center M_n with radius MO to establish point O_n. On O_nM_n as base draw a triangle congruent to OMN, and thus establish point N_n. Now a tangent from N_n to the pulley cuts the other involute e_N at S_n which establishes the distance N_nS_n corresponding to elongation of the spring between the two positions of the pulley. A similar construction using involute e_N establishes congruent tri-

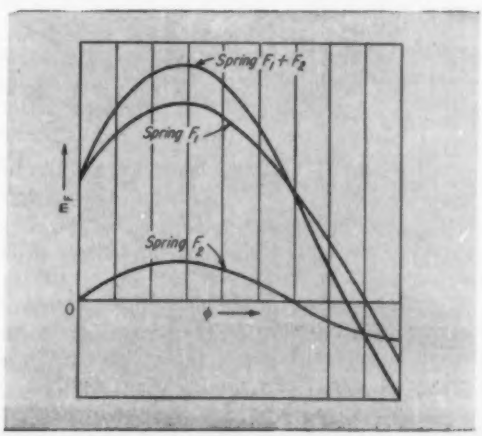
continued on next page

SYMBOLS

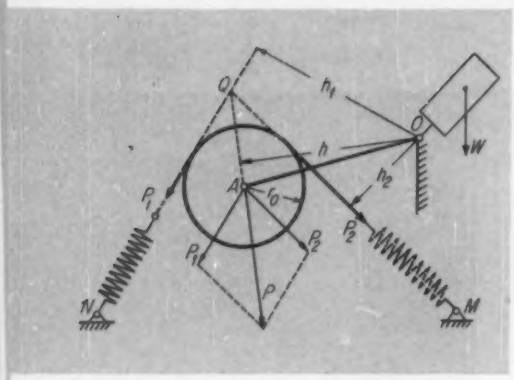
a—Free length of spring, in.
b—Spacing between points 0 and M, in.
c—P/f, spring-rate constant
d—Wire dia, in.
D—Coil dia, in.
f—Spring elongation, in.
G—Shear modulus, 11,500,000 psi
h—Spring moment arm, in.
k—Spring index factor
m—Moment, lb-ft
n—Number of coils
ρ—Length of weight lever arm, in.
ϕ—Displacement angle, degrees
r—Length of spring lever arm, in.
P—Spring force, lb
v—Weight moment-arm, in.
W—Load to be balanced, lb
$\sigma = \frac{r_o}{R_o}$, Ratio of differential pulley radii



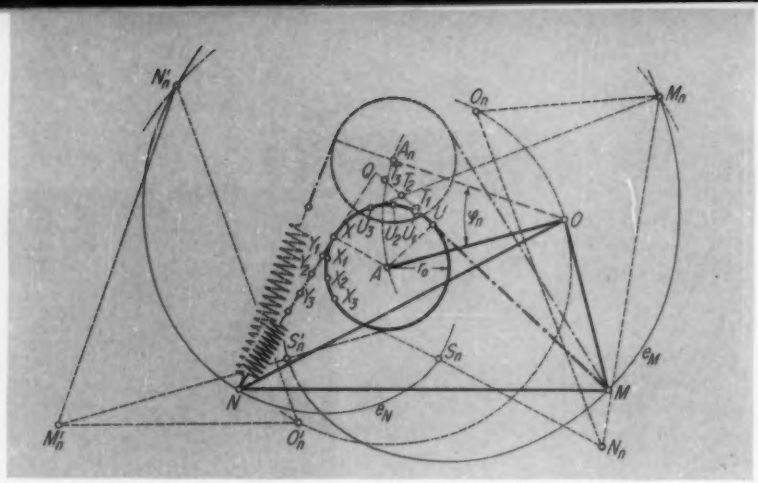
3(A)—ONE SPRING WITH LONG LEVER ARM can do the work of two springs with shorter lever. But sometimes two springs give better flexibility.



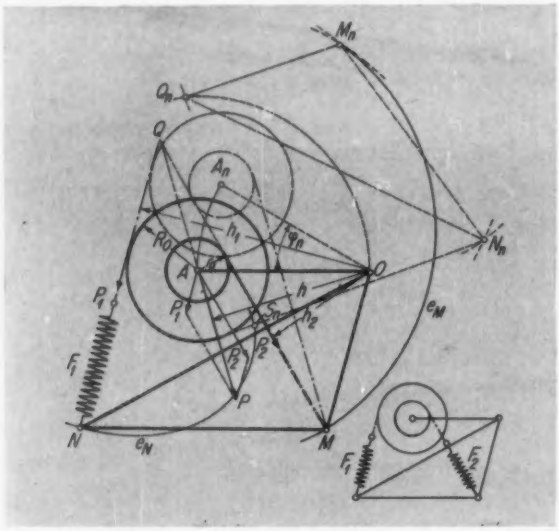
3(B)—TO REPLACE TWO SPRINGS WITH ONE, the balancing moment of resulting spring must be the algebraic sum of the two springs.



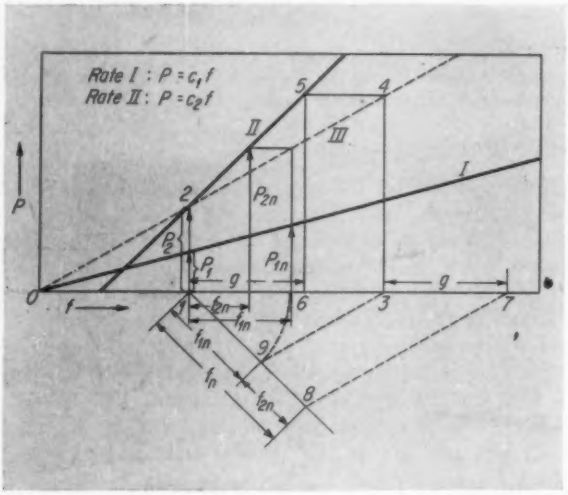
4—SPRING WITH SWINGING PULLEY is another way to provide suitable balancing moments.



5—REQUIRED SPRING EXTENSION N_nS_n for each balance point is determined by involute layouts.



6—DIFFERENTIAL PULLEY gives wider choice in determining suitable lever-arm lengths.



7—SPRING-RATE CURVE LAYOUTS help determine deflections and forces when two springs are used with a differential pulley,

angles NOM and $N'_nO'_nM'_n$, and the distance $M'_nS'_n$ which is equal to N_nS_n, the elongation of the spring.

Differential pulley

A differential pulley can be used in several ways to balance a load moment, as in Fig 6. Here, a single spring can apply tension to a rope around either the large or the small pulley. In either case the pulley itself must be in equilibrium, which requires that $P_1R_o = P_2r_o$. From this the spring-actuated moment results in:

$$m_F = Ph = P_1h_1 + P_2h_2$$

Spring extension for each position of the pulley can be determined graphically as in Fig 5.

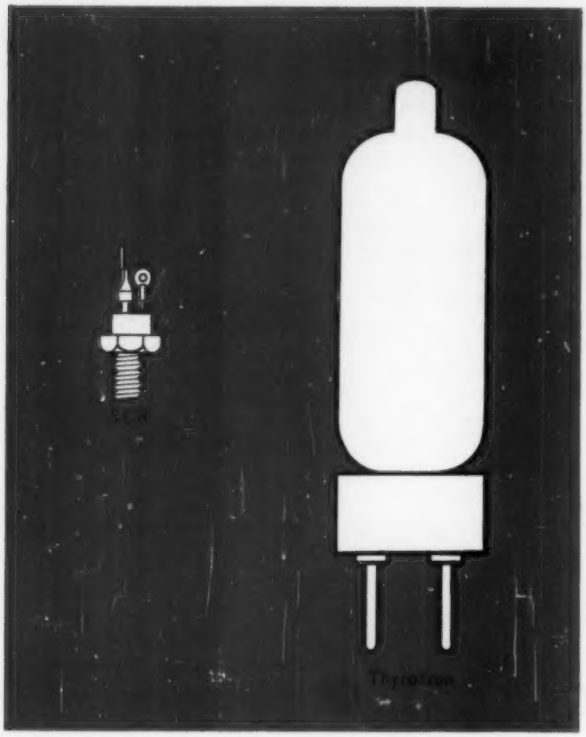
With two springs on a differential pulley the solution is somewhat more involved, but the procedure is the same as for one spring. While springs can have identical or different spring rates, the ratio of the spring forces P_1/P_2 must be equal to σ, the ratio of the radii, r_o/R_o.

For either one or two springs, relationship of the spring forces can be simplified by drawing the spring rate curves as shown in Fig 7. Here, curve I is spring rate for spring F_1, II is for spring F_2, and III is spring rate for an equivalent spring $F_1 + F_2$. The spring forces and elongations correspond to the angular displacement of the pulley from A to A_n. Point 3 is an arbitrary point from which an ordinate is drawn to point 4, and then a horizontal line to point 5 and another vertical line back down to point 6. Length g of the intercept between points 1 and 6 is measured, and an equal length g from point 3 defines point 7. On any inclined line through point 1 the distance from 1 to 8 is now marked off equal to N_nS_n in Fig 8, and a line from 3 to 9 is drawn parallel to the line joining points 7 and 8. Point 9 divides the line segment 1 to 8 into the spring elongations f_{1n} and f_{2n}, which completes the graphical construction of Fig 7. The ordinates of these points give P_{1n} and P_{2n}, the spring forces at A_n.

Spring elongations f_{1n} and f_{2n} can also be calculated:

$$f_{1n} = \frac{f_n}{\frac{1}{\sigma} \cdot \frac{c_1}{c_2} + 1}, \qquad f_{2n} = \frac{f_n}{\sigma \cdot \frac{c_2}{c_1} + 1}$$

where f_n is the combined equivalent spring elongation, and c_1 and c_2 are spring-rate constants for springs F_1 and F_2. ■



COMPARISON OF SIZES shows that SCR is smaller than thyratron needed for same job. For example, 2-in. SCR's replace 8 or 9-in. thyratrons in the power circuit for a 3-hp motor.

which controlled rectifier—

SCR or Thyratron?

The silicon controlled rectifier, a solid-state device, might seem only a new version of the gas-filled thyratron . . . but it is vastly different, and usually better. This article tells how and why.

BARUCH BERMAN, *chief engineer*
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An early oversimplification in describing the versatile new silicon controlled rectifier (SCR) has caused some controversy over terminology. At first the SCR was called "solid-state thyratron" by engineers and authors alike, because it resembled the well-known thyratron more than anything else.

But this was really a misnomer because the two look entirely different and have significantly different operating characteristics. The SCR is a fraction the size of the thyratron, is many times faster and is suited to a greater variety of control jobs.

To be sure, there are many applications where either rectifier would be satisfactory. But there are many other cases where the choice should be the SCR—and designers aren't always aware of its advantages. This up-to-date guide presents the information you need to choose the right one. For ready reference, the table on p 31 summarizes the most important points.

Compactness is the SCR's best-known advantage. Because it's a semiconductor, it can be much smaller than its thyratron counterpart, which contains an appreciable volume of inert gas or vapor. Their relative sizes are indicated by the sketch above.

Mechanical strength and resistance to shock of an SCR are good because the basic structure is compact and lightweight. With proper mounting it is virtually indestructible. On the other hand, the thyratron—a gas-filled glass tube containing a heated filament—is more susceptible to mechanical shock and must be treated with care.

Electrical conductivity of the solid-state SCR is better than that for the ionized xenon or mercury gases used in thyratrons. Further, SCR's can operate efficiently at lower voltage levels and have terminals much closer together, thus reducing length of electrical path. Voltage drop in the thyratron is 10 or 15 v; in the SCR, only 1.5 v.

One advantage of the SCR's low voltage drop is that ordinary low-voltage supply lines (120 and 240 v) are sufficient to drive a load at good efficiency.

Many controls using thyratrons require higher supply voltage (with transformers) to reduce the effect of the

WHAT IS A CONTROLLED RECTIFIER?

■ The thyratron and SCR (silicon controlled rectifier) are common examples of controlled rectifiers—3-terminal electrical switching devices that allow large current flow in the forward (rectifying) direction when a small signal is applied to the control (gate) terminal. No current flow is allowed in the reverse direction.

When a controlled rectifier is "triggered" (made conducting in forward direction) it will remain conducting even after trigger signal is removed. To shut it off requires reducing the forward current to a level below the specified holding current, or reversing the potential across terminals. The rectifier then quickly returns to its nonconducting state until retriggered. There are other ways to turn off the device, but they are not common in power switching.

The thyratron—older of the two controlled-rectifier types—is an electron tube filled with gas (usually xenon or mercury vapor). It has three electrodes, and can be made to conduct current between main terminals (anode to cathode) when the proper *voltage* signal is applied at the third (gate) terminal.

The SCR—also known as Trinistor, Thyrode, and so forth, —is a silicon solid-state device. It also has three terminals and it conducts current from anode to cathode when the proper *current* signal is applied to a third terminal. Note that gate signal is current, not voltage, for SCR.

Major area of application for any controlled rectifier is in modulation of power—such as is needed to control speed of motors or vary intensity of electric lights (see Editor's Note). Ac supply is commonly used, and power is modulated by turning the rectifier on for only a portion of each cycle with magnetic triggers so that power is being transmitted only part of the time. The average power transmitted depends on ratio of on-time to off-time.

higher voltage drop. High-voltage transformers and other components require more expensive design to avoid corona, arcing, and insulation breakdown.

Auxiliary devices in the thyratron's circuit also contribute to voltage losses. The SCR circuit uses silicon diodes and other solid-state elements—all with relatively high efficiency. The thyratron circuit uses gas-type rectifiers, which have relatively high voltage drop and high starting voltage—adding to the heat loss.

Efficiency of an SCR is considerably higher than that for a thyratron as a result of these combined factors: better conductivity, shorter electrical path, and operation without need for heated filament. With higher efficiency less heat is wasted and less surface area (and therefore volume) is needed to dissipate it.

Over-all losses in an SCR are about 20 w for a 1-kw device, compared with 150 w for an equivalent thyratron.

Warmup is eliminated with an SCR, because conduction —a molecular solid-state phenomenon—can begin instantly. Since there are no startup-voltage requirements, power can be applied to gate (triggering terminal) and anode simultaneously. The device actually functions as a solid-state circuit breaker and needs no external contactors.

A thyratron, on the other hand, can be damaged if load is applied before the cathode heats up. To prevent accidental triggering during this period, relays, contactors, and other components with moving parts are sometimes added to the circuit. Such components can arc and wear. Also, a time-delay relay is needed to defer application of the anode voltage until after warmup is complete. This takes at least 30 sec.

Instant operation of equipment is possible if cathode of thyratron is kept continuously hot. But this wastes heat energy during no-load conditions and produces variations in starting voltage of the tube. Starting voltage is usually highest (40 to 80 v) following periods with no load. After load is applied, voltage decreases; it then needs a few seconds to stabilize.

The cathode heater is sensitive to voltage variations, which ought to be limited to about ±2% of rated value. When power lines aren't regulated that closely, separate regulators are sometimes used to improve performance.

Startup: SCR is triggered by a low-level current signal. It is relatively unaffected by spurious, high-impedance voltage signals nearby.

Thyratron is triggered with a voltage signal (required "swing" may be 40 to 80 v, depending on tube characteristics). It is susceptible to spurious signals nearby, so shielding, or short leads are required.

Shutoff with SCR is extremely rapid (about 20 microsec or less); it explains why this type of control works well in single-phase and polyphase circuits, even at high power.

Thyratron shutoff takes 50 times as long—about 1000 microsec—because its gas must de-ionize. (During conduction, gas in the tube is ionized.) After conduction stops, if high, fast-rising inverse voltage is applied, the anode attracts and collects ions, sputtering in the process.

Polyphase circuits, and those with a thyratron used as rectifier for inductive-type loads, show greatest evidence of the sputtering problem. This is why thyratron inverters and three-phase controls have not been extensively developed.

Waveform of output is smoother with SCR circuit than with thyratron type. This means that lower peak voltage and current values are needed to give same average power output. Benefit here is that motors and other equipment driven by SCR can be made smaller and designed for lower potential or current peaks. In most cases, standard motors can be used.

Most operating characteristics that are important in circuit operation and device output are relatively more stable for the SCR than for the thyratron.

Current ratings are usually higher for SCR than for thyratron. However, SCR is limited to 500 v peak inverse voltage, whereas thyratron can operate in higher voltage circuits. SCR as a rule can handle more over-all power than a thyratron, but there are other tube-type controlled rectifiers such as ignitron and xantron that cover the higher power ranges.

SCR vs Thyratron—comparison at a glance

SIZE	SCR—smaller (it's a semiconductor). Thyratron — many times larger (needs heater filament, surface area to dissipate heat; wider spacing of electrodes to support higher voltage).
MECHANICAL STRENGTH	SCR—Not as susceptible to vibration and shock. Thyratron—relatively fragile.
ELECTRICAL CONDUCTIVITY	SCR — solid-state phenomenon; voltage drop only 1.5 v. Thyratron—conduction by ionized gas; voltage drop, 10 or 15 v.
WARMUP TIME	SCR—none. Thyratron—at least 30 sec. (Needs separate voltage supply for heater.)
OPERATING TEMP	SCR—from −85 to +300 F. Thyratron—from −70 to +165 F.
STARTUP	SCR—triggered by current; needs no startup voltage. Unaffected by spurious signals. Thyratron—triggered by voltage; startup voltage between anode and cathode must be about 40 v or more; sensitive to spurious signals.
SHUTOFF	SCR—20 microsec. Thyratron—1000 microsec.
OPERATING CHARACTERISTICS	SCR—relatively more stable at all loads. Thyratron—triggering and startup voltages vary with load cycle, because of varying heating and cooling in cathode.
TYPE OF CURRENT	SCR—works on both single and polyphase, even at high power. Thyratron—sputters and has poor commutation in polyphase applications because of slow ionization and deionization.
CURRENT RATINGS	SCR—available up to 50 amp and over. Thyratron—available up to about 25-amp average anode current.
JOGGING	SCR—gives constant rate with simple circuitry. Thyratron—constant rate harder to achieve because firing point varies with many conditions, particularly tube temp.
ADDED CONTROLS	SCR—current-limiting controls are easy to add, using transistors and other solid-state or magnetic devices. Thyratron—additions are cumbersome because gas-tube characteristics must be matched.

Voltage pulses higher than rated are not desirable for any controlled rectifier. However, the thyratron will "stand off" higher voltage spikes because of its inherent physical construction.

Jogging (conducting in small but regular bursts of power for short periods) is easy with an SCR. The firing angle can be preset with the proper circuitry, and the SCR will fire each cycle at this same point (as long as the start button is down) with very little deviation. The SCR jogs without moving parts—no clicking, arcing or flashing accompanies the operation. Jogging is useful for such applications as motor-speed control, where short runs at medium or low speeds are sometimes desired.

With thyratron, when power is low the firing angle is greatly affected by cathode temperature and heater voltage. Cathode temperature at startup is usually lower than at operating condition, and therefore jogging rate may drift as cathode temperature is stabilizing.

Special circuitry is relatively easy to make when using SCR's in combination with other solid-state devices such as transistors, tunnel diodes, and zener diodes. This is because they are all compatible and respond similarly to voltage and temperature variations. Thyratrons can also be used in such circuits, either with other tube-type components or with semiconductors (hybrid circuits). But because of their different nature they are more cumbersome and the design is more difficult to perfect.

Power and control conductors in SCR circuits can often be run in same conduit or cable—which would be undesirable when operating with thyratrons. Voltage spikes in nearby power lines will be picked up in control circuit of thyratron if unshielded, and cause erratic operation. Shielding of control conductor's is not necessary with SCR.

Controlled reversing of dc motors is possible with all controlled rectifiers. SCR units, however, can eliminate the external contactors needed in thyratron-type circuits—the SCR can be its own solid-state circuit breaker. A future article will discuss details of a new design.

EDITOR'S NOTE. Thyratrons and SCR's have been topics of many recent articles on motor controls:

What They're Offering in Electrical Controls, Sep 26 '60, p 37—Describes new SCR-controlled reversible variable-speed dc motor designed by author Baruch Berman. Look for future article comparing it with other older controls.

New Speed Control for Dc Motors, Aug 15 '60, p 41—Concerns another SCR control invented by Mr Berman—this one for ordinary nonreversing variable-speed dc motors. Circuit schematic and performance curves are given.

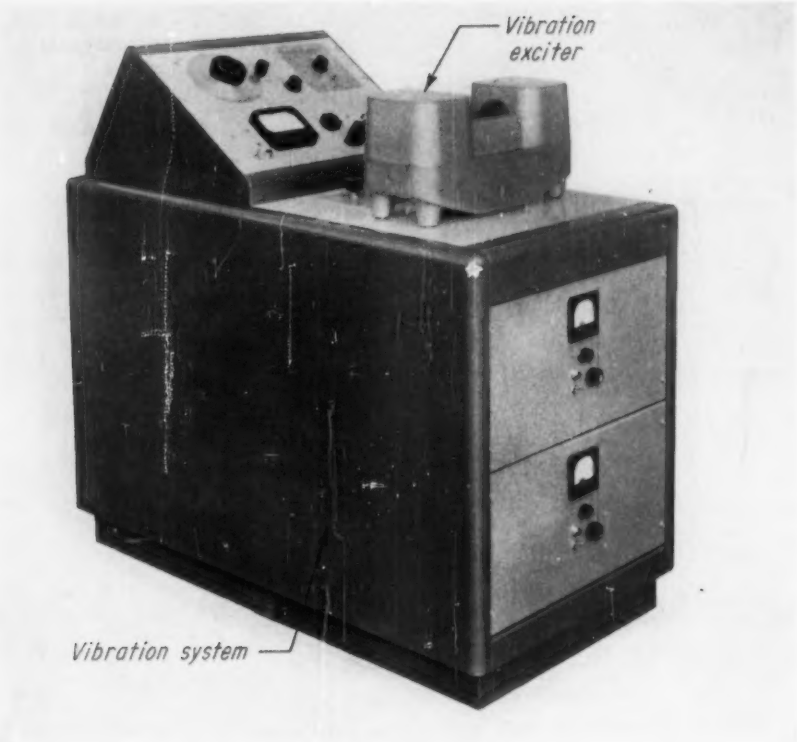
Frequency-controlled Ac Motor, Aug 8 '60, p 42—Shows how tunnel diodes and SCR team up to drive ordinary ac motor at variable speed (experimental only).

New Dc Motors, Mar 31 '58, p 108—A description of a thyratron-controlled watercooled dc motor controlled through both field and armature to give wide speed range.

New Variable-speed Motor Drive, Mar 28 '60, p 80—Evaluates new reactor-capacitor drive for dc motors, comparing its performance with thyratron-type and other drives.

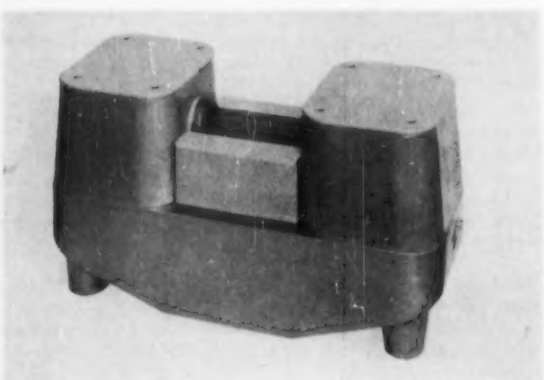
How the thyratron works is lucidly described by analogy in this previous article:

Pneumatics Simulates Electronics, May 9 '60, p 39—an experimental air device actually works like a controlled rectifier.



Floating table controls vibration

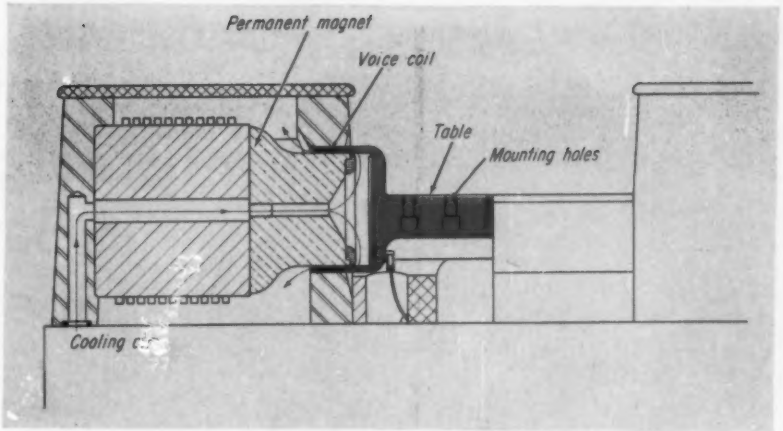
Air bearings support the moving element of this vibration exciter and confine its motion to the proper axis. Push-pull drive avoids structural resonance.



VIBRATION EXCITER has a U-shape arrangement of magnets which is, in effect, a massive tuning fork. Since the arms of a tuning fork move in opposite directions, the motion is cancelled; and induced vibrations in the stationary frame and equipment are effectively cancelled before they reach the vibration table. A high ratio of stationary mass to moving mass (approx 100:1) eliminates the need for tie-downs or clamping.

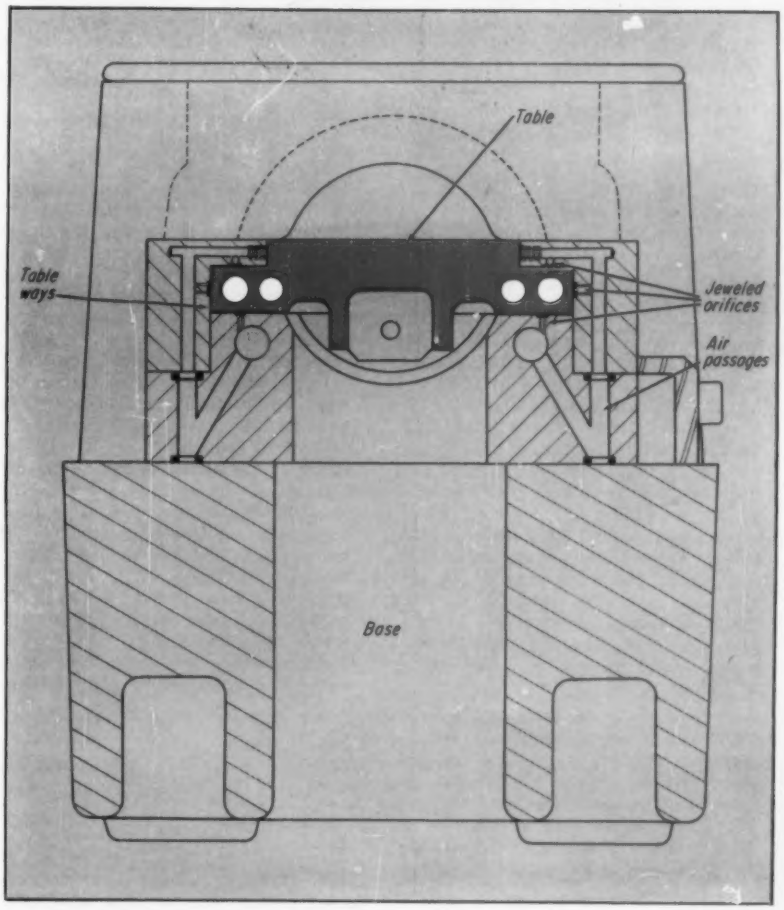
TWO VOICE-COILS provide constant ratio between input and output of the drive through the full travel of the table. Single-voice-coil drives of conventional vibration tables produce a varying ratio between input and output as the relative position between the movable coil and fixed field changes. But with a voice coil at each end, a compensating push-pull effect is produced. As one coil moves out of its field (and output is reduced), the opposite coil moves into its field (and output is increased). This results in precise reproduction of the input waveform in vibratory motion.

The permanent-magnet field eliminates undesirable field hum and simplifies the filtering of background noise This reduction of outside interference permits the unit to produce an accurate sine wave at vibration magnitudes as low as 0.1 g with better than 10:1 signal-to-noise ratios at frequencies of 5 to 2,000 cps. A secondary advantage is that the permanent-magnet field generates no heat; an air blast cools voice coils. Wire coils permanent magnets are used for initial magnetization only and left in place for economy —they cost more to remove than their scrap value is worth.



AIR SUSPENSION floats the vibration table and mounted specimens, providing the low friction inherent with air bearings. Except for attachments to the test specimen, the table has no mechanical connection or contact with equipment or supports. This isolates the vibration table from the interference of extraneous vibrations caused by uncontrolled sources. Cross-talk vibration caused by outside forces along axes other than that intended is reduced to a negligible amount. High vertical spring rate (20,000 lb/in. at 7 psig air) and uniform loading of the table's air bearings allow random placement of the test specimen without producing unbalancing effects.

The air bearing is formed in a tongue-and-groove arrangement between horizontal U-shape ways. Air is bled to the bearing surfaces through 12 sets of jeweled orifices, two to a set. Jeweled orifices are used to obtain the critical diametrical accuracy required and reduce air erosion of the hole. Clearance between table rails and ways is 0.0005 in. and orifice sizes are proportioned to air-support the table without contact.



PS . . . Horizontal vibrator has a displacement of 0.5 in., is capable of a 50-lb force output at frequencies up to 50 kc. It can also be used as a shock-testing machine for short-duration shocks of extremely high amplitude. Maximum shock amplitude is in the order of 5000 g with a duration of 1½ milliseconds. Shocks can be repeated up to a rate of 5 per sec. Model ST-100 Vibration Exciter can be supplied with complete vibration and shock systems (Model 1201 shown) by ITT Industrial Products Div, International Telephone & Telegraph Corp, San Fernando, Calif.

Springs Save Energy in Satellite Tape Recorder

They maintain constant tension in tape, yet offer resistance only half the time. System has been used successfully in the two Tiros weather satellites.

TAPE RECORDER is a link in the system used to send cloud-cover pictures from the Tiros I and Tiros II weather satellites. At a preprogramed time, focal-plane shutter flashes a picture on a light-persistent screen for 1.5 millisec. An electron beam with 500 lines per in. scans the image for two sec. This information is stored on one of the tape's two tracks for future transmission. The other track holds instrument data. As the satellite passes over a ground station, it transmits the stored data from two tape recorders. One recorder is for a wide-angle camera, which takes pictures of an 800-mile-wide path, and the other is for narrow-angle camera, which takes pictures of an 100-mile-wide path. It takes 1.5 sec. for the transmission from each camera. The 400 ft of 1.5-mil polyester tape moves at 50 in. per sec. and stores 32 photos.

CAPSTAN pulls tape from the upper of the two stacked reels during recording cycle. Drive for the takeup reel underneath is through the spring motors which link the two reels. One end of each spring attaches to the hub of the upper reel and the rest of each spring coils up in an individual case mounted on the web of the lower reel.

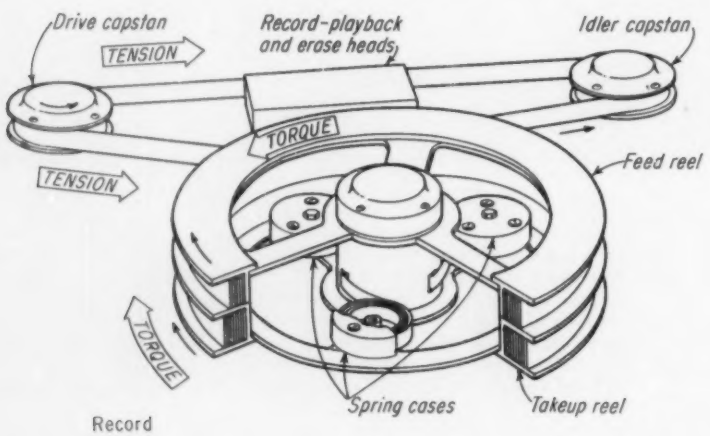
Curvature of the spring causes it to wind up inside the case and exert a pull on the fixed end. This pull is essentially constant, no matter how much of the spring is out of the case.

Initially, the springs are wound on the hub of the feed reel. During the first half of the record cycle, the takeup reel rotates faster than the feed reel and the springs coil up in the three cases. During the second half of the cycle, the feed reel rotates faster than the takeup reel, and the springs are wound back around the hub. The rotation of the two reels relative to each other depends on the amount of tape on each. The springs are 167 in. long to allow for the 22 relative revolutions each half-cycle.

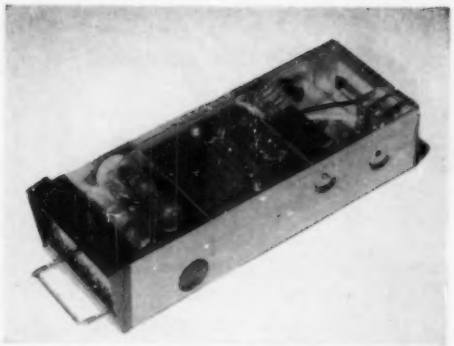
During the first half of the recording cycle, takeup reel has less tape—hence smaller diameter—than the feed reel. This produces a net torque on the capstan in the direction of rotation and assists the drive. After the midpoint, the takeup reel has more tape, so the net torque reverses and hinders the drive. But this hindrance only occurs for half the cycle; in the usual friction-drag system, a mechanical brake or motor on the feed reel opposes the drive during the entire recording cycle. The springs also eliminate a torque motor on the takeup reel which drains power, adds weight.

Over short intervals, the torque of the spring motors is more constant than that of an electric motor; this reduces flutter.

Synchronous motor for the capstan reverses for rewind. At the same time signals are transmitted, backwards, to the ground, where they are unscrambled by playing the receiving recorders in reverse. During rewind-transmit, action of the springs is similar to that of recording cycle.

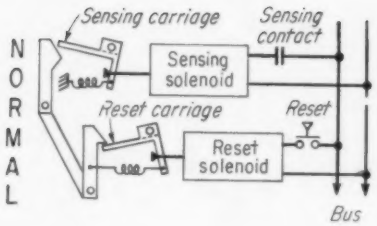


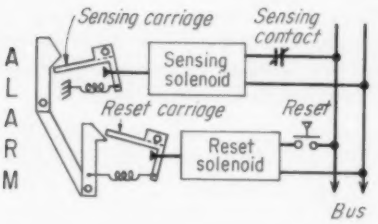
PS . . . Power for the 8-watt synchronous drive motor comes from nickel cadmium batteries, recharged by solar cells. A transistorized converter changes dc to 512-cycle ac. Tape transport is 13-in. dia, 4-in. high, weighs 5 lb, 10 oz. Made by Astro-Electronics Div, RCA, Princeton, NJ. Negator spring motors are manufactured by Hunter Spring Co, Div of American Machine and Metals, Lansdale, Penna.

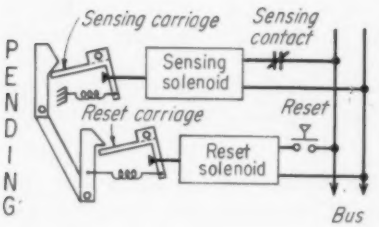


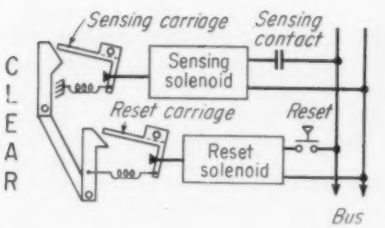
Switches Tilt to Sound the Alarm

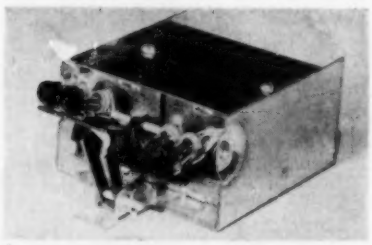
When trouble occurs, two carriages move up or down in response to conditions. Mercury switches clipped to them control circuits, trip lights and buzzers.







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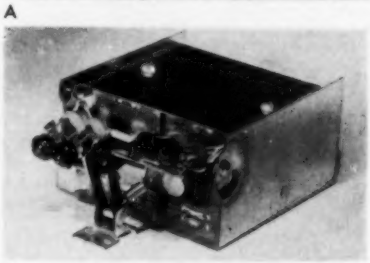
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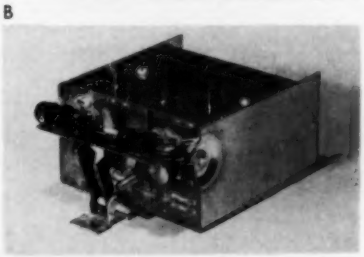
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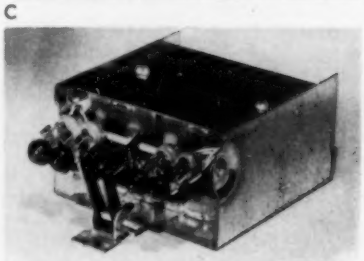

D

SOLENOID-ACTUATED CARRIAGES can accommodate up to three mercury switches each. Circuits can be changed from normally open to normally closed simply by reversing mercury switches in spring clips. Space on switch carriage allows additional switches as interlocks, lockouts, or supplemental indications.

Alarm annunciator has two mercury switches plus red, green and white bulbs. These combine in a four-step sequence when alarm conditions arise. Normally (A) window nameplate is dark, sensing carriage is raised and reset carriage is latched. When trouble develops (B), sensing contact is closed and sensing solenoid is energized; this depresses sensing carriage and trips latch to release reset carriage. When reset carriage rises, mercury switches energize bright white light behind annunciator window and sound audible alarm. Operator acknowledges alarm (C) by pressing reset button; this energizes reset solenoid, which latches reset carriage down. Red light behind annunciator window turns on to show that corrective action is pending, and audible alarm is silenced. When the alarm condition is cleared (D) the sensing contact is opened, releasing the sensing carriage. As it rises, the sensing carriage trips latch to allow reset carriage to rise. Green annunciator light turns on and audible signal sounds to indicate alarm conditions have been corrected. Operator presses reset button to depress and latch reset carriage; audible signal shuts off and light behind annunciator window goes out.

PS . . . Over-all dimensions of plug-in annunciator drawer are 2⅛ x 3½ x 8¾ in.; an illuminated window 1-9/16 x 3¼ in. identifies the function being monitored. Red, white and green bulbs behind annunciator window indicate conditions and buzzer can be incorporated in the circuit for audible alarm. Units plug into racks, which can be made in any vertical and horizontal combination of units. Electro-pane is produced by Electro Devices Inc, St. Louis.

these ways to solve

INTRICATE DIECASTINGS

Simplify the diecasting and it can be fabricated cheaper. But what if you are designing a complex part? Here's a review of familiar rules—and how to bend them to your needs.

Good design practice for diecastings usually calls for simplifying the part. But this does not preclude using the same method when complex parts are needed—the fact is that many intricate parts are produced cheaply by die-casting. This, however, requires considerable finesse. You must not only know the rules for good design but also how to get around their demands for simplicity.

Designing the part

Intricacy in diecastings costs little more than simplicity —after the die is made. Even while making the die, many details can be had merely for the price of machining. And they can be beneficial too—such intricacies as ribs stiffen the part while providing channels for flow of molten metal.

However, the basic economics of die-making cannot be ignored. And here, we find that largest increase in costs will come from adding movable elements to the die assembly. Furthermore, these elements must be properly aligned so that they will not widen critical tolerances.

Avoid undercuts and reentrant angles because collapsible cores cannot be used. However, undercuts can be cast if loose pieces are inserted into the die, and then ejected with the part. The risk here is that a loose die piece, improperly placed, can ruin the entire die.

Do not cast intersecting holes or passages because these may require expensive intersecting cores. It is cheaper to core one hole and drill the other. However, if intersecting holes must be cored, then one hole should be at least twice diameter of the other.

Add draft or taper on cores for easy ejection from the die. If taper cannot be used, design the part so core is in the parting plane, or specify minimum draft for a portion of the hole.

EDITOR'S NOTE: This article is based on a set of internal standards from the Bell Telephone Laboratories, and an interview with the author of these standards, W. P. Brander.

Walls with holes should slope enough for the die halves to form the hole, and eliminate a separate core. However, if the hole is to be drilled, make the wall perpendicular to axis of the hole.

Specify regular curves and contours that can be machined by a round-nose milling cutter. If more complex shapes are needed, electro-machining processes, while more expensive, are practical for many intricate shapes that previously could not be formed except with expensive handwork.

Avoid separate inserts that slow down the process. But where properties of another metal are necessary the inserts can simultaneously provide undercuts.

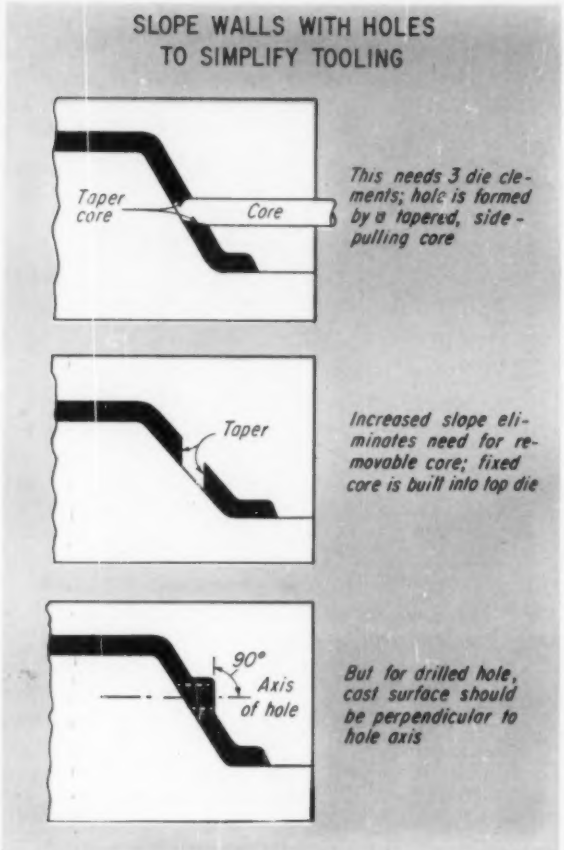
Combine inserts to minimize handling and make them large enough to be easily handled through asbestos gloves. If location from insert to insert is critical, join them by welding, or seat them in the mold so that they will not be displaced by the injected metal. To prevent loosening, mechanically lock the inserts by die-casting against a knurl or groove, or a roughened surface if expensive inserts must be salvagable.

Avoid long, slender cores—especially those that form blind holes. Beyond the ratios given in the accompanying table it is preferable to core part of the hole and then drill the remaining depth.

Keep walls thin and uniform. Minimum wall for zinc-base alloys is thinner than for magnesium and aluminum —but these two can be made in thicker sections (for carrying heavier loads). On the other hand, zinc diecastings can stand more abrupt changes in section.

Avoid cast threads. Internal threads are particularly impractical because the core must be unscrewed. Better way: Core the hole, then tap it. Specify depth on tapped holes. A sufficiently deep tapped thread in zinc will shear a steel bolt before the threads will strip. Another alternative is to use self-threading inserts.

External tapered-pipe threads and Acme threads can be die-cast. Rounded threads are easier cast than sharp


SLOPE WALLS WITH HOLES
TO SIMPLIFY TOOLING
Taper core
Core
This needs 3 die elements; hole is formed by a tapered, side-pulling core
Taper
Increased slope eliminates need for removable core; fixed core is built into top die
90°
Axis of hole
But for drilled hole, cast surface should be perpendicular to hole axis

V-threads. Square threads should not be cast. Long threaded portions should be avoided.

For external threads the mold is parted through the axis. A small flat at the parting line will allow trimming away flash—more practical than cleaning out the thread by chasing.

Avoid sharp corners and deep projections that trap air and retard flow of metal. But if necessary, air traps can be vented and metal flow improved by extra gates. Deep ribs can be divided into several small ones. Although this requires more metal for the same stiffness, shallow ribs can aid casting because they provide extra channels for metal flow.

Avoid holes at an angle. They require special core-pulling devices which are expensive to build into the die. Curved cores must be pulled along an arc, so are even less practical. Angled holes can be produced but are particularly uneconomical in the parting plane.

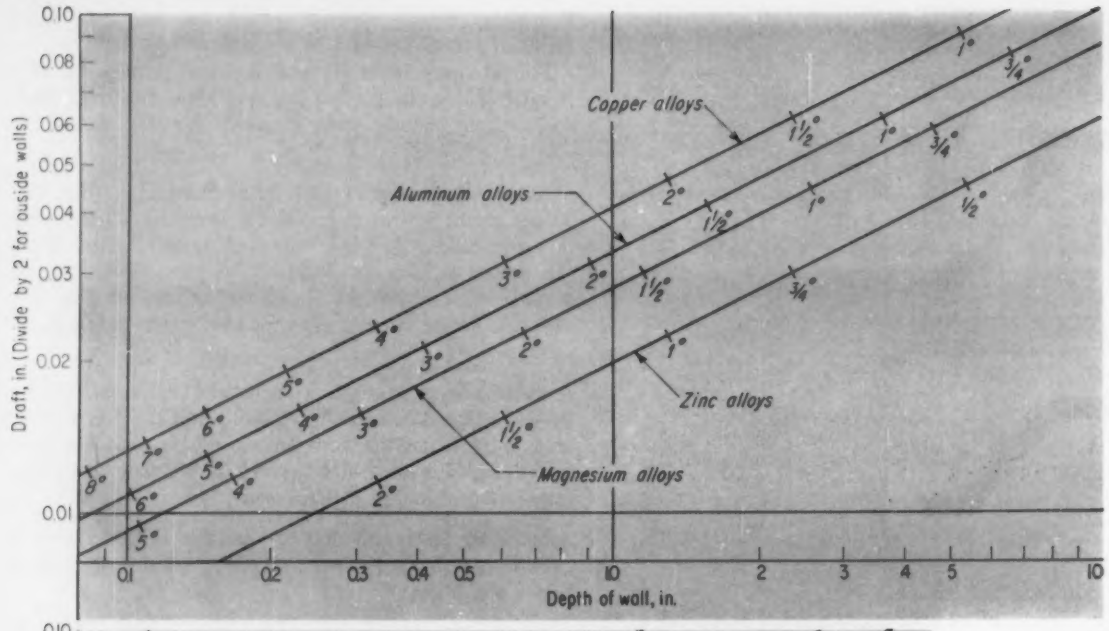
Space the holes and slots to eliminate thin die sections between. Through-holes are preferred because they allow better core support.

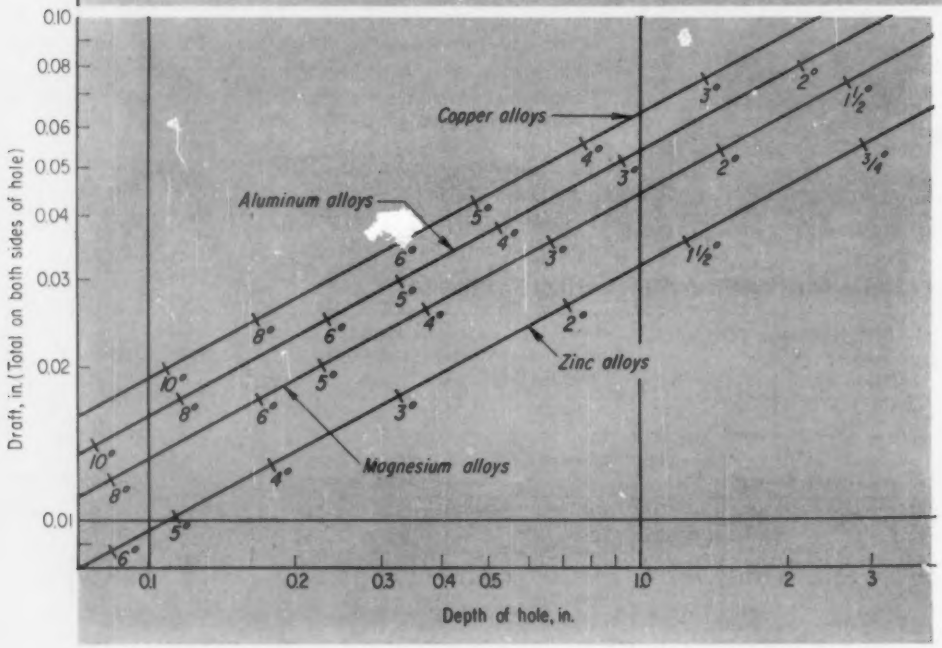
Avoid unnecessary surface detail to avoid sticking in the die. But across large dimensions, flat surfaces transmit shrinkage stresses to die parts. Bosses, ribbing or beading minimize stresses for longer die life and visually break up the surface to hide minor surface blemishes.

Minimize machining. This removes the sound, high-strength cast skin while increasing costs. But when you must cut into the diecasting, note these sections on the

Tolerance and Shape Limits for the Four Diecasting Families

MATERIAL	DIMENSIONAL TOLERANCE						CROSS-SECTION, in.		CORED HOLES		
	Linear, in.				Flatness, in.						
	Size of part	critical	noncritical	general	add across parting line	dimension in.	tol., in.	Max dim.	Min wall thickness	Min dia., in.	Dia., in.	Max depth, diameters
Zinc Alloys	up to 2 in.	0.003	0.006	0.016	0.005	up to 3 in.	0.008	< 4 4 to 8 8 to 12 12 >	0.047 0.062 0.078 0.094	0.094	up to 0.250	3 to 8 X
	for each additional in.	0.001	0.0015	0.0015		for each additional in.	0.003				0.250 to 1.00	6 to 8 X
Aluminum Alloys	up to 2 in.	0.005	0.008	0.016	0.010	up to 3 in.	0.008	< 4 4 to 8 8 >	0.062 0.078 0.094	0.100	up to 0.250	3 X
	for each additional in.	0.0015	0.002	0.002		for each additional in.	0.003				0.250 to 1.00	3 to 5 X
Magnesium Alloys	up to 2 in.	0.005	0.008	0.016	0.010	up to 3 in.	0.008	< 4 4 to 8 8 >	0.062 0.078 0.094	0.100	Up to 0.250	3 X
	for each additional in.	0.0015	0.002	0.002		for each additional in.	0.003				0.250 to 1.00	3 to 5 X
Copper Alloys	up to 2 in.	0.010	0.016	0.031	0.010	up to 3 in.	0.008	< 4 4 to 8 8 >	0.094 0.109 0.156	0.188	up to 0.50	1½ to 3 X
	for each additional in.	0.003	0.003	0.003		for each additional in.	0.003				0.50 to 1.00	3 to 5 X





drawing. Porosity usually can be shifted from such areas. For parts that must mate, add enough machining stock so that the tool will cut below the skin of abrasive oxide. Here, the cut should be shallow enough to avoid breaking through to porous areas. The normal machining allowance is: minimum, 0.005 in., and maximum, 0.016 in., for small surfaces such as bosses—and 0.031 in. for larger surfaces or a number of surfaces machined to a common plane.

Keep the casting simple. An overly complex diecasting may be more cheaply produced by dividing it into several castings—then fastening them mechanically or by adhesive bonding. But a one-piece complex part has better tolerances and is without joints that need sealing.

Which material?

A more fluid metal is preferable because it flows more easily into an intricate shape. In general, metal with a lower melting range is more castable.

Zinc-base alloys can give more intricate diecastings than aluminum or magnesium, therefore should be chosen if they meet mechanical requirements. Radii can be smaller and walls can be thinner without misruns. The comparatively low melting range for zinc alloys eliminates "die soldering" (sticking of molten metal to the die). This means less die wear and better tolerances on the part. Also, it is easier to electroplate zinc-base alloys without special preparation. The zinc alloys commonly used, AG40A and

AC41A (ASTM Spec), are generally interchangeable. Their impact strength is high, and ductility is good enough for a limited amount of post-forming. Their yield strength is not clearly defined because of creep at room temperature, and they lose their mechanical properties above 200 F.

Magnesium-base alloys are next higher in melting range, are the cheapest per cu in. and also the lightest, and are easiest of all to machine. The standard ASTM alloy AZ91B has high tensile strength, toughness, and fair resistance to corrosion. But Mg decorative and protective finishes cost more than do either zinc or aluminum.

Aluminum alloys have good structural strength and form an adherent oxide film that often requires no further surface treatment. Dimensional tolerances for aluminum are similar to those for magnesium but die wear is slightly higher.

Two alloys, A380 and 13X, are used for most aluminum diecastings. The 13X has better castability and is better for thin or complex parts. Its silicon content increases fluidity and gives sound sections. The better castability may give higher actual strength in an intricate part than is obtainable from a stronger alloy with poorer castability. But this 13X alloy is hard to machine and its silicon gives a poor-looking anodize. The 380 alloy is less castable. Part of the silicon here is replaced by copper, to make the alloy stronger and more ductile, and give better anodizing.

Other special and higher cost aluminum alloys combine good castability with high strength, elevated-temperature service, resistance to corrosion, ease of machining, or good anodizing properties. Anodized parts require more surface preparation and cost 10 to 15% more.

Copper alloys are used for intricate parts only where their high mechanical strength is required. This is because they are the most costly material, and have highest melting range and shortest die life. Three materials are available: Z30A alloy, a low-cost brass with good machinability; ZS331A, easier to cast for complex parts, has higher strength but is harder to machine; ZS144A has the highest mechanical strength, hardness and wear resistance but is hardest to cast and machine. The Z30A is easily tinned for solder connections.

A checklist

Specifying all the requirements will help design of tooling for the castings. It will also point out ways to improve the casting without sacrificing performance. Planned changes at this stage will avoid expensive die changes later. Accordingly, complete information should be given:

- Give the tolerances on all dimensions. These should start from a common datum plane even if nonfunctional holes are added to form the plane.
- Indicate maximum permissible draft, and its direction, to prevent interference with assembly.
- Note all sections to be machined. Give the dimension to be obtained after machining.
- Specify special requirements not usually considered a commercial standard:

a. Permissible leakage and the fluid to be contained.
b. Abnormally high or low temperature.
c. Freedom from porosity in a machined section.
d. Freedom from surface marks or flash.
e. Undistorted flat surfaces.
f. Electroplate or anodized surfaces.
g. Special strength requirements and their nature—torsion, bending, twisting, tension.
h. Special corrosion exposure other than ordinary indoor atmosphere—high humidity; marine, mine, or industrial use; contact with chemicals.

Details for diecastings

Linear and flatness tolerances are larger for higher melting alloys. Those in the table are slightly broader than in most references to help reduce cost for large quantities.

Draft recommendations for inside walls and cavities are given in the two charts on facing page. On outside walls, draft can be ½ that for inside walls.

Fillet radius, generally at least 0.060 in., may be as sharp as 0.015 in. for small castings. To mate with an external sharp corner, extend one of the walls beyond the corner to form a groove with a generous radius.

Where fillets join unequal sections, radii should be kept to the average thickness of the two sections. Fillet radii should be larger in the higher melting alloys because the higher pressures cause die-checking where metal flow changes sharply in direction. Die-checking is less for zinc, which is cast with lower pressures and temperatures.

Bosses for fastening should be heavy. When they merely act as locating points or spacers, or to increase depth of the part for stiffness, boses can usually be cored to reduce the amount of metal. Cores used for these nonfunctional purposes are commonly called "metal-savers." Ejector bosses can also be lightened by "metal-saver" cores.

Wall thickness for small areas under best casting conditions can be 0.030 in. for zinc, 0.040 for aluminum, 0.050 for magnesium, 0.060 for the copper alloys. More practical minimums for each material are given in the table. For the sections over 12 in., the minimums are for shallow walls; deep-wall sections should be thicker.

For REPRINT of above article, just check P76 on one of the Reader Service cards found in this issue.

EDITOR'S NOTE: For further details on designing diecastings and how to finish them, see:

How to Specify Finishes for Magnesium, June 6 '60, p 31—Selection guide to the most suitable finish methods, including chemical treatments and organic coatings for best properties at lowest cost.

Aluminum Diecastings — the Field Widens, May 9 '60, p 48—Details on a new alloy and an improved process which promise broader applications; gives design tips for die casting with aluminum.

For Small Parts . . . Zinc Die-casting Cuts Costs, Apr 18 '60, p 65—Inexpensive, single-cavity method with built-in finishing tools gives up to 300 parts per minute and tolerance as close as ± 0.0005 in. It's best suited for minimum runs of 100,000 pieces.

Specifications for Anodized Finishes, Sep 28 '59, p 44—Change the aluminum alloy, its surface preparation, or the coating process—and your finish can change. Article shows how it will look and tells how it will perform.

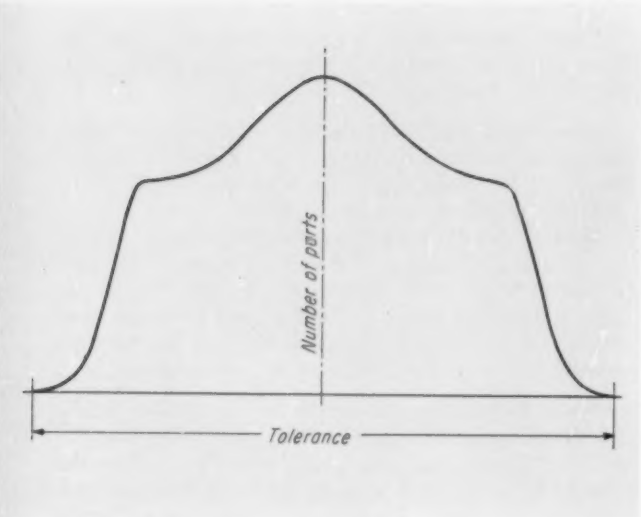
Which Finish for a Zinc Diecasting, Mar 3 '58, p 58—A guide to mechanical, chemical plating and painting methods to get a quality part without losing economy of die-casting.

Graph sets

SAFE TOLERANCE FOR CUMULATIVE DIMENSIONS

When design keeps adding on dimensions (poor practice, but not always avoidable) this graph will help establish an over-all tolerance that is neither too conservative nor too risky.

E R WOLFF
General Purpose Control Dept
General Electric Co
Bloomington, Ill



NEITHER RECTANGULAR NOR GAUSSIAN, this diagram shows how dimensions of parts could be distributed within the tolerance range if parts were made on a punch press. Tool wear causes dimensions to shift from one end of the range to the other over the life of the tool—but there are few parts at either end because tools were not perfect to begin with and because they are discarded before completely worn out.

Design for mass production commonly sets tolerances by considering the statistical chance of misfit. But statistical tolerances are not always realistic tolerances. In many kinds of manufacturing processes, the dimensions simply refuse to distribute themselves to fit the statistician's convenient bell-shape curve. Realistic tolerances are a particularly critical matter when a large number of toleranced parts are stacked together. It is then that tolerances multiply and far wider variations in the over-all dimension may occur than would be expected from statistical computation.

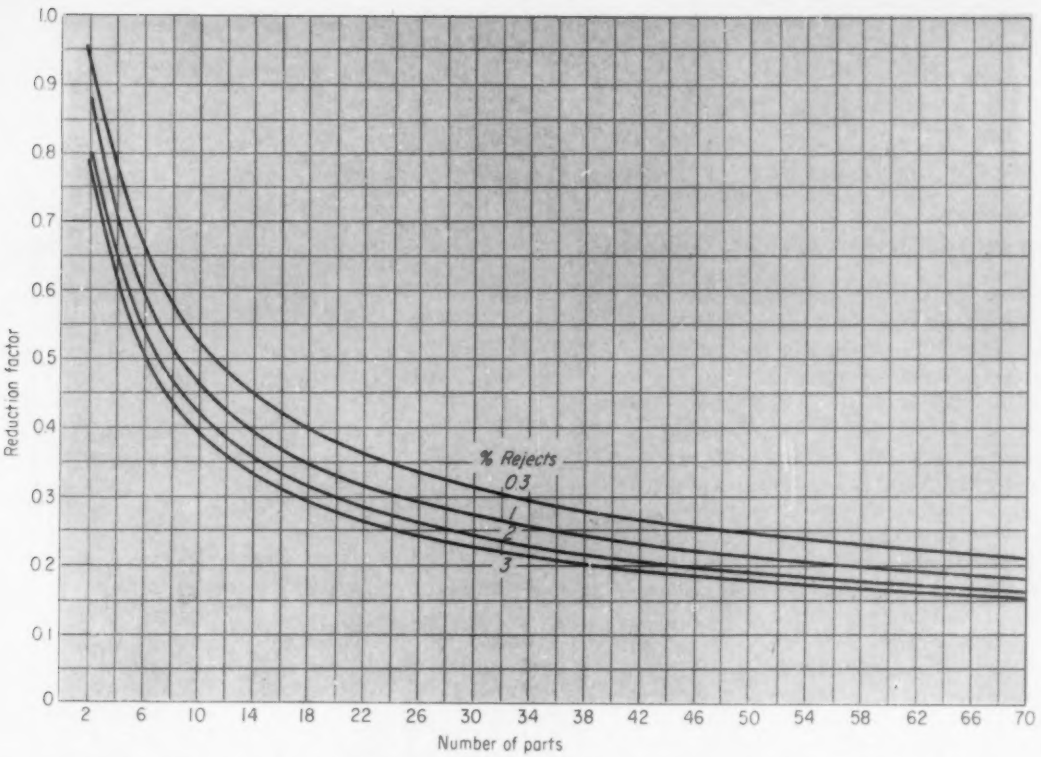
But this doesn't mean that the only over-all tolerance for a stacked assembly is the accumulated total of individual tolerances. If a slight percentage of rejects is permitted, statistics will still help set tolerances that are narrow enough to ensure a good fit, yet not so narrow that a large number of assemblies will have to be scrapped, reassembled, or reworked. A simple equation and a graph quickly establish the appropriate reduction in over-all tolerance.

Two statistical distributions . . .

In a batch of machine-made parts, the way dimensions are distributed between the two extremes of tolerance depends on the manufacturing process and the inspection and drafting procedures. Generally the designer assumes either of two distributions:

- In "normal" production most parts fall in the center of the range and very few at the extremes. A plot showing number of parts vs dimension is a bell-shaped curve—the statistician's "normal" or Gaussian curve.
- In "uniform" production there is an equal chance that any part will have any dimension within the range. In this case, the plot is a rectangle.

The choice of distribution can make a big difference in the tolerances the designer specifies. If tolerances are ± 0.003, for example, a design for a normal distribution would assume that 68.3% of the parts will fall between ± 0.001 while with a uniform distribution, only 33.3% of the parts would fall in this range.



REDUCED CUMULATIVE TOLERANCE depends on number of stacked-up parts and desired reject level. Reduction factor applies only to assemblies having parts with equal tolerances. When parts have different tolerance ranges, find equivalent-equal tolerance from equation in text.

Part distribution

In many cases, it is decidedly risky to set tolerances by assuming a normal distribution. One place for possible disagreements with that smooth, bell-shape curve is in the way a dimension is specified on the drawing. If you specify a nominal dimension and a plus-and-minus tolerance, it is possible that dimensions will, in fact, spread out in a normal pattern. But if you specify only upper and lower limits it is fair to assume that the shop will aim for a dimension anywhere within the range. Thus any dimension within the range has roughly an equal chance of occurring and instead of a Gaussian curve, a rectangular pattern will be more likely.

The shape of the distribution pattern will also depend on the manufacturing process. When parts are made of soft materials, or when there is little tool wear, the shop will probably turn out more parts with the nominal dimension. But tool wear is often a significant factor. It is common for the toolmaker to make his punch and die sets, for example, so that they initially produce parts at one end of the tolerance range. Then, as tools wear, the part's dimensions shift to the opposite end of the range. In making a hole punch, the toolmaker will try to get as close to the maximum hole as possible; so that it will wear to the minimum.

The distribution of such dimensions is closer to a rectangle than a normal curve. However, there will be some deviation from a rectangle because the toolmaker will probably not succeed in making a tool that starts exactly at one end of the range and, furthermore, the tools will probably be discarded before they reach the end of their useful life.

Other factors also affect the distribution pattern. When all parts come from one machine, there is less chance that dimensions will be normally distributed, unless parts are cut and measured on a one-at-a-time basis. Quality-control inspection will also cause deviation from the normal pattern. When inspectors reject parts that fall outside the tolerance limits, the effect is to cut off the tails of the curve and, in severe cases, to turn a normal curve into a rectangular one.

Assembly distribution

For a number of reasons, then, the rectangular distribution is a closer approximation of the actual distribution. But when parts with a rectangular distribution pattern are stacked together, the distribution of the cumulative dimensions is not rectangular. The probability that the over-all dimension of stack will fall in the center of the accumulated-tolerance range is better than the probability that it will fall at either extreme. This is because there are a number of combinations that will give parts in the center of the range and only a few combinations for the extremes. If an assembly has two parts, with ± 0.004 tolerances, for example, there is only one combination (-0.004, both parts) that will give a deviation of -0.008. But there are

five combinations that will produce assemblies with no deviation.

The more parts in the assembly, the more this effect is accentuated. For an assembly with a large number of cumulative dimensions the distribution of the cumulative tolerances approaches a normal distribution.

The graph at the top of page 41 tells how much over-all tolerances can be reduced to take advantage of this effect. Suppose an assembly has five parts stacked one on the other and each part has a tolerance of ±0.002. According to the graph; the cumulative tolerance of ±0.010 can be reduced to 65% to give tolerance of ±0.0065 with only 1% of the assemblies falling outside this range.

The graph was drawn on the assumption that all part tolerances are equal and rectangularly distributed. In actual practice equal tolerances occur only rarely. But you can still use the graph for these unequally toleranced parts if you first compute an equivalent-equal tolerance H:

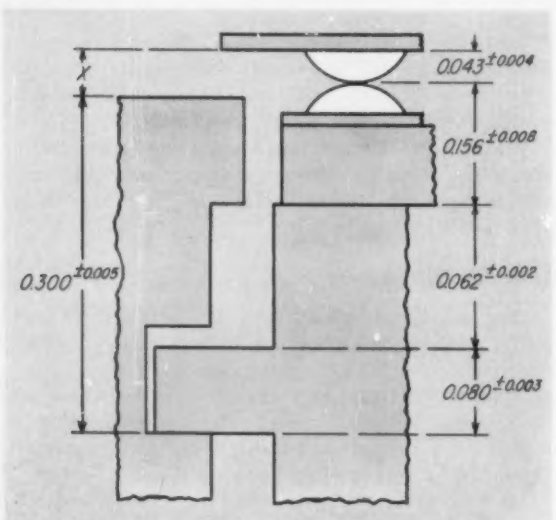
$$H = \sqrt{\frac{(P_1 \times a_1^2) + (P_2 \times a_2^2) \ldots (P_n \times a_n^2)}{W}}$$

where a is the tolerance range of any part, P is number of parts with that tolerance and W is total number of parts. Then the sum of equivalent-tolerance range Z (not the same as the sum of unequal-tolerance ranges) is

$$Z = WH$$

This is the sum that is corrected by the reduction factor read from the chart.

Example 1



These parts of a contact assembly for a relay are dimensioned as shown in the sketch above. The dimension X is the intentional amount of overtravel (called "wipe") of the upper contact which would occur if upper contact were clamped to the part at left. How much will wipe vary if assemblies are manufactured for a 2% reject level?

Summing dimensions, wipe is 0.041 and, from the arithmetic sum of tolerances, wipe tolerances are ±0.022. But computing an equivalent-tolerance range (for convenience, tolerances are divided by 0.001)

$$H = \sqrt{\frac{3^2 + 2^2 + 8^2 + 4^2 + 5^2}{5}}$$

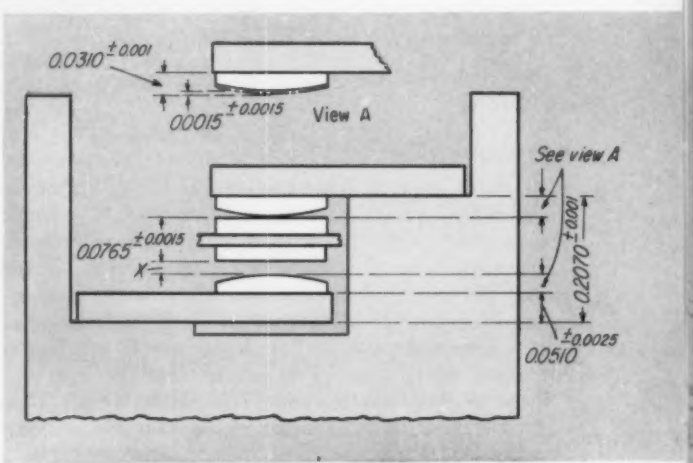
$$= \sqrt{\frac{118}{5}} = 4.86$$

$$Z = HW = (4.86)(5) = 24.3$$

and referring to the graph, 5 parts and a 2% reject level gives reduction factor 0.59. Thus total tolerances are actually

$$(24.3)\ (0.59) = 14.3$$
$$X = 0.041 \pm 0.0143$$

Example 2



What are the variations in the gap of the relay contacts shown above?

Nominal dimension of the gap is sum of part dimensions.

$$X = -0.0765 - 0.0310 + 0.0015 + 0.2070 - 0.0510$$
$$- 0.0310 + 0.0015 = 0.0205$$

Equivalent equal tolerances are

$$H = \sqrt{\frac{3\ (1)^2 + 3\ (1.5)^2 + (2.5)^2}{7}} = 1.51$$

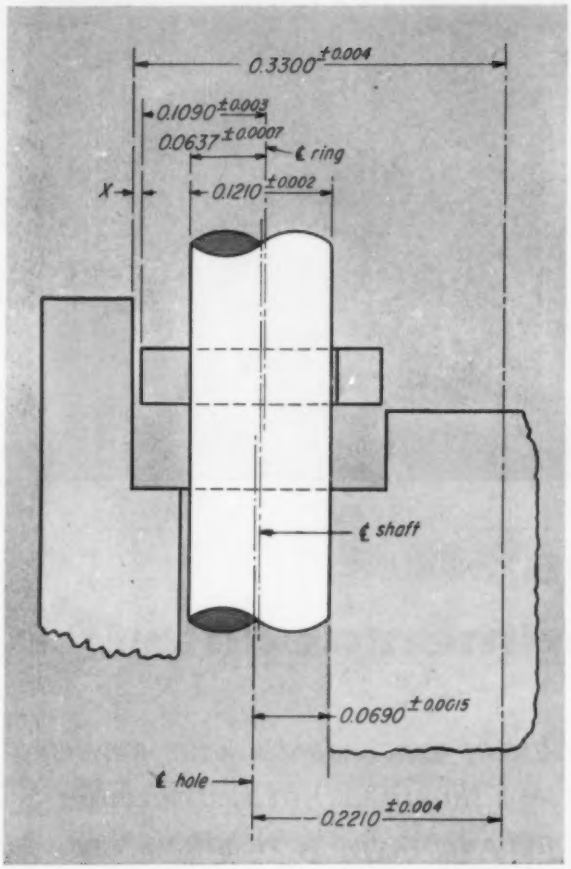
and equivalent range is

$$Z = (1.51)\ (7) = 10.58$$

For 1% reject level, tolerances are

$$(10.58)\ (.55) = 5.82$$
$$X = 0.0205 \pm 0.0058$$

Example 3



A shaft, ring, and hole are dimensioned as shown in the sketch above. Summing dimension and tolerances shows that clearance is 0.0117 ± 0.0152 giving an interference of 0.0035 for the worst possible combination. What is actual tolerance if reject level is set at 1%?

Equivalent equal tolerances are

$$H = \sqrt{\frac{2\,(4)^2 + 3^2 + 2^2 + 1.5^2 + 0.7^2}{6}}$$

$$H = 2.82$$

and accumulated equivalent tolerance is

$$Z = (2.82)\ 6 = 16.9$$

From graph, reduction factor gives tolerance range for 1% level as

$$(16.9)\ (0.59) = 9.9$$
$$= 0.0117 \pm 0.0099$$

giving a minimum clearance of 0.0018 for 99% of assemblies produced.

To speed computation, we have turned these problems over to an IBM 650 computer. There is a deck of machine-language cards for each reject level and once the cards are loaded, each solution requires about 10 seconds. The computer will handle a maximum of 35 dimensions in each of 35 different tolerance ranges (for a possible total of 1225). Besides the result, output card lists number of dimensions W, equivalent equal tolerance H, sum of equivalent tolerances Z, and reduction factor. The reduction-factor curves were programed into the computer with a curve-fitting routine based on a 5-term polynominal.

EDITOR'S NOTE: Five previous articles describe other ways to set statistical tolerances:

Factors of Safety in Tolerance Specifications, Mar '53, p 155. A statistical method maintains precise dimensional control of interchangeable parts.

How to Evaluate Assembly Tolerances, Jan '53, p 179. Statistical methods set tolerances on any assembly of production parts.

Probability Applied to Assembly Fits, Nov 25 '57, p 88. For short-run production, mathematical probability sets tolerances that are just as reliable as those set by conventional (but more complicated) methods.

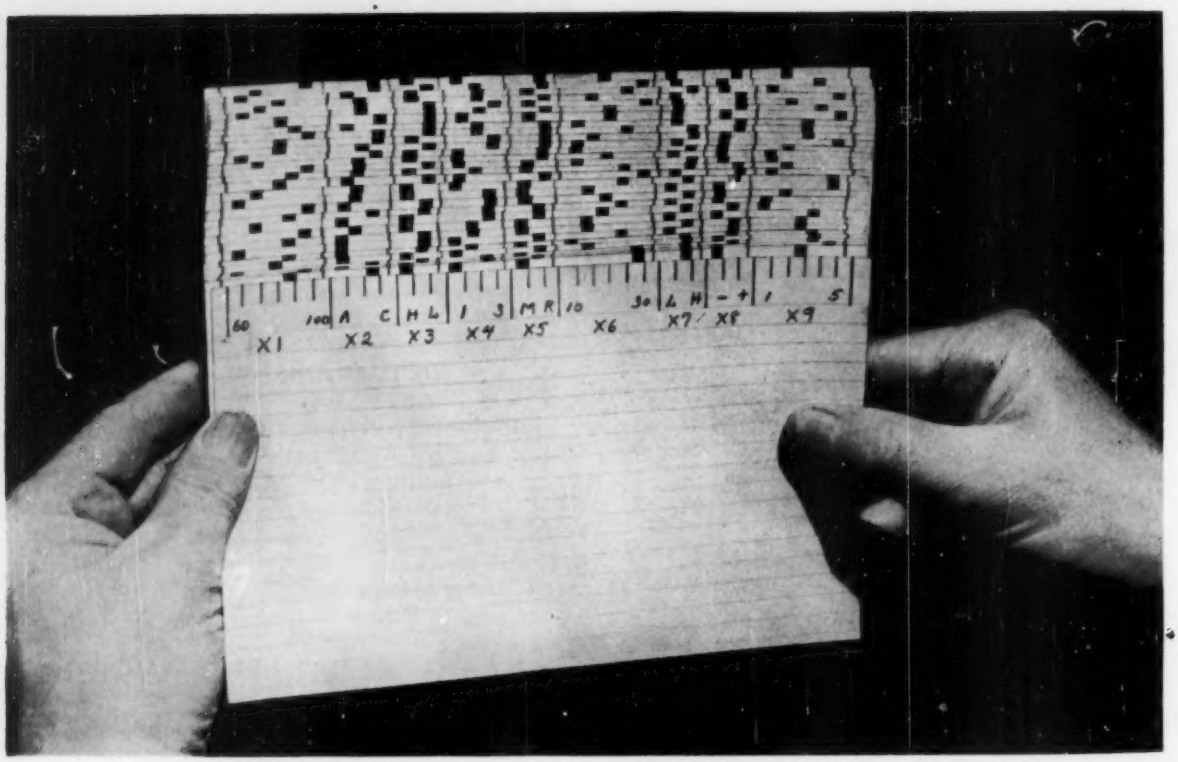
Equations Predict Chance of Misfit in Assembly. May 26 '58, p 61. Check your statistical tolerances with these formulas. They work for assemblies containing any number of parts, tell how many reject assemblies to start on.

A Faster Way to Set Statistical Tolerances, Mar 21 '60, p 55. Table quickly tells number of misfit assemblies for two parts with any chosen degree of tolerance overlap.

For other recent articles on tolerances, see:

Vectors Simplify Tolerance Analysis, July '57, p 195. A graphical method for pile-up of tolerances when dimensions are nonparallel and nonrectangular.

The Use of Tolerance Systems, Feb '56, p 164. Recommended tolerances with particular emphasis on the ABC tolerance system; tables give tolerances for clearance, transition and interference fits.



EDGE-CODED CARDS —they analyze experimental data

Spotting the significant variables in a mass of experimental data is much easier if you can scan hundreds (or perhaps thousands) of two-variable graphs. With these coded cards, you simply arrange the results in the order you want and the graphs plot themselves.

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Statistical Engineering Institute
Wellesley, Mass

One of the chief reasons for running an experiment is to find which input variables affect the output and which do not. With standard statistical methods, this is not overly difficult if there are only five or six variables. But suppose there are 10, 20 or more? How do you find the one input, or combination of inputs, that makes the most difference in the output? Even statisticians boggle at the thought of manipulating 25 variables without losing control of at least one.

The answer is surprisingly simple. Record the data so that the effect of each input plotted against the output, or against other inputs, can be seen and examined. But in many experiments this requires that you plot and glance at as many as 5000 two-variable graphs. The trick is to code the data on the edge of file cards, then stagger the cards to reveal meaningful patterns. Though the method is statistically sound, you don't have to know much about statistics to use it. Even a technician can run experiments and analyze them when data are prepared this way.

Analysis of data is not the only difficulty in a polyvariable (10, 20 or more) experiment. You must first decide how to organize the experiment so that the eventual analysis will be valid. Until recently, there was no way of handling this many variables. Classical statistical methods were inadequate to cope with the complexities of, say, a 20-variable experiment.

EXAMPLE

In testing a machine, find the effect of 9 input variables on 3 output variables. Some inputs can be varied over a continuous range (for example, air temperature, x_3: 70 to 90 F, and timing signals, x_9: +4 to −4) while others are 2-level variables (oil pressure, x_5: low and high, and different types of accessories, x_7: A and B). Choose levels for each of the continuous variables and arrange them in an experimental design containing 30 runs.

To randomize the levels of each variable turn to a random-number table. Variable x_1 has 5 levels so there will be 6 runs for each variable. Starting in the middle of the random-number table, read off numbers in order and write down the first 6 numbers between 1 and 30. Suppose they are 8, 17, 2, 5, 30, 24. Assign the first level to these runs. Continuing in the table read off 4, (17), 11, 25, (5), 13, 28, 15. Ignoring duplicates (those numbers in parentheses), assign the second level to these runs and complete the assignment for the other levels of x_1 in the same manner. Repeat the procedure for each of the other variables. Completed table looks like this.

Runs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
X_1	12	4	8	6	4	8	10	4	8	10	6	8	6	10	6	12	4	8	10	10	12	10	12	4	6	12	8	6	12	4
X_2	60	80	80	70	70	60	70	80	80	60	80	60	70	60	70	60	60	70	80	80	80	60	70	70	80	80	70	60	70	60
X_3	90	70	90	70	90	90	70	90	70	90	70	70	90	90	70	70	70	90	70	90	90	90	70	70	90	70	70	70	90	90
X_4	200	180	180	180	190	180	190	200	200	190	200	180	200	190	180	200	190	200	180	200	190	190	190	200	190	180	190	200	180	180
X_5	L	H	L	L	H	H	L	L	H	L	L	H	L	H	H	H	L	H	L	H	H	L	L	L	H	H	H	H	L	H
X_6	130	120	130	135	130	140	135	140	125	125	120	125	140	120	130	140	135	120	140	135	135	120	125	125	140	130	125	130	120	135
X_7	B	B	A	B	A	A	B	B	B	B	A	B	A	A	A	B	B	A	B	A	B	B	A	A	A	A	A	B	B	A
X_8	C	C	C	D	D	D	D	D	C	D	D	C	D	D	C	C	C	C	C	C	D	D	C	C	C	D	D	D	C	D
X_9	+2	+2	−4	−4	−2	+4	+2	−2	0	0	+2	−2	+2	0	−4	+4	−4	0	+4	0	−2	−2	−4	−2	+2	−4	+4	+4	0	+4

example continued, next page

But in 1956 we discovered that a simple random arrangement of variables and levels of variables would, in fact, give statistically significant results. The easiest of these randomly arranged experiments is called random balance. It will handle as many as 100 variables and requires, in some cases, as few as 30 experimental runs. (By contrast, all possible combinations of one hundred 3-level variables would require 60×10^{46} experimental runs.)

Why polyvariable?

There are many advantages of a method that will attack all the variables at once rather than individual investigation of only a selected few. First, for the same investment of time and money, the polyvariable experiment will give much more information. Theory and experience show that there is an almost-linear relationship between the number of variables and the amount of information you'll learn about the machine or process being tested. Second, there is no risk that you will overlook an important variable. Many experiments have failed because the engineer, in his attempt to reduce the experiment to a few manageable variables, excluded one that had an important effect on the output. With polyvariable experiments you can include even the least suspicious variables without much increase in experimental complexity. Further, there will be a reduction in the amount of administration because the methods are not difficult to learn and are versatile enough to avoid those parameters that are not easily varied.

How many variables should you choose? The answer is to include all having a conceivable affect on the output. Review the list to make sure none of these are omitted. It has been our experience that many experiments fail because the engineer in charge eliminated one variable that "couldn't possibly have any effect." In re-analysis, this is the first place we look. But because the advantage of the method is to get quick answers, exclude any variables that are not easy to change. If there is no provision for adjustment (a part that may affect output is welded in position, for example) save the adjustment of this variable until you have looked into all the other possibilities.

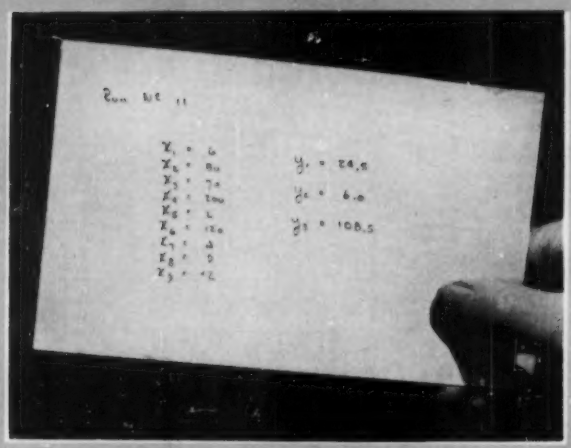
With a list of variables at hand, you are now ready to set up the experiment. Start by choosing the number of levels for each variable. Three is convenient though there may be some variables where two levels will do (a low and high value, for example) and others that are unusually sensitive or cover such a broad range that 4 or 5 levels are necessary.

The number of runs in the experiment depends to some extent on the number of variables. Thirty runs is usually

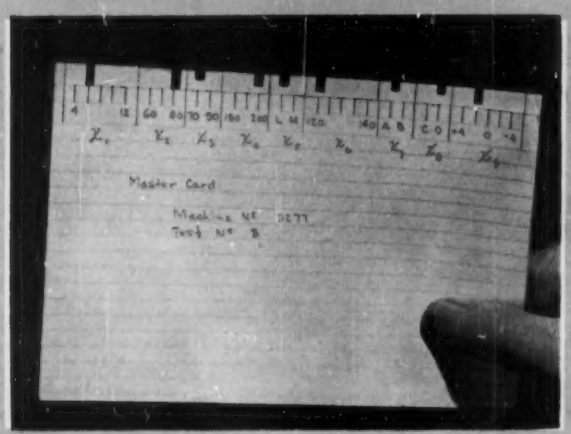
text continued, p 47

EDGECODING EXAMPLE continued

In addition, choose one run which you repeat at random five times during the experiment. These additional runs are not included in the final data but are examined to determine repeatability of equipment and accuracy of measuring instruments. Data from each run are recorded on an 8 x 5-in. file card as shown below.

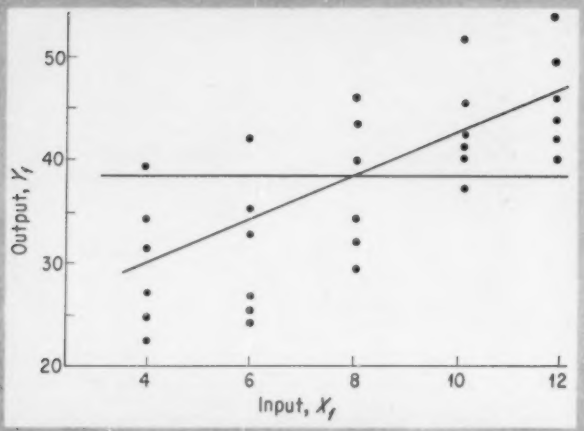


Input variables are coded on the edge of the card, using the scales marked on a master card, like this:

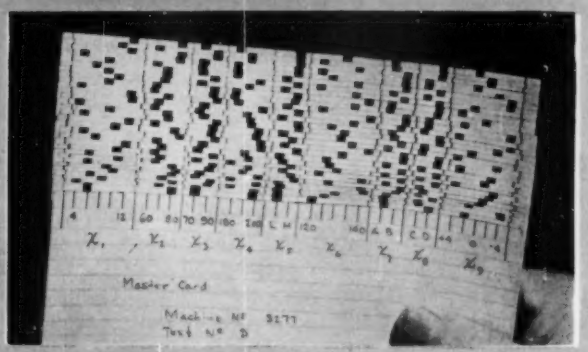


With all the data recorded and coded, arrange the cards in order of increasing y_1 output. When the deck is skewed to expose the coding marks there appears to be a strong relationship between the x_1 input and y_1 output, as shown below. All other inputs appear scattered.

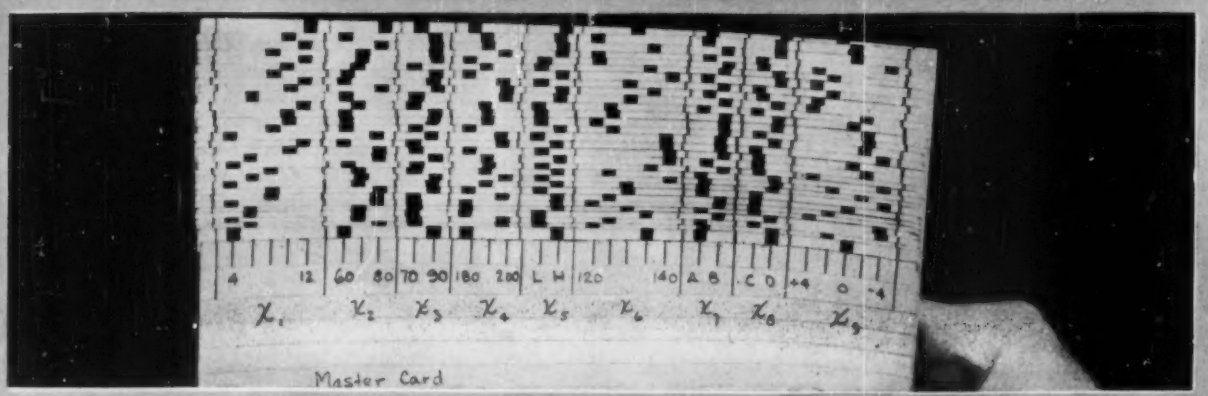
To see this relationship in proper perspective with a plot showing the magnitude of y_1, replot y_1 vs x_1 on ordinary graph paper.



But there is a chance that the effect of variable x_1 is masking a minor effect of another input. What would results have been if x_1 had been held constant at 8? To correct the output, first draw a trend line through the scattered data and then draw a horizontal line to show average output if x_1 had been constant at 8. The difference between the two lines is the correction factor: add 8 to y_1 for all runs where x_1 was 4; add 4 when x_1 is 6; subtract 4 when x_1 is 10; subtract 8 when x_1 is 12. The cards are then rearranged according to this corrected output and the edgegraphs reexamined.



This shows that the x_1 input has a definite relationship to the y_1 output. The same procedure is followed to analyze the effect of the inputs on the y_2 and y_3 outputs. These results show the best combination of inputs.



adequate for the first experiment, even if there are 20 or more variables. You may want to add more runs when you have the data from this initial experiment to point out critical areas. Select the levels of each variable in each run of the experiment by consulting a random-number table (see example, p 45, for details).

Now check to be certain that this random selection did not produce an experiment with an impossible combination of variables. Also, you might wish to look at some selected pairs of variables to be sure most combinations of levels are included. If, for example, two 3-level variables are examined and one combination is not represented (there are 9 possibilities) a new set of randomly selected levels should be chosen for these variables.

Coded cards expose data trends

When you are satisfied that the experiment is truly randomized, choose one of the 30 runs at random and repeat it randomly (three to five times) among the other runs. This will give you a measure of your experimental precision.

Run the experiments in order and list the data from each on a separate 5 x 8 in. data card. This is where the special coded cards come in. To code them, first prepare a master card with a space at the edge for each of the input variables. The space provided for each variable will depend on the number of levels; a 4-level variable will take twice the space of a 2-level variable. Label the space and divide it to indicate the different levels. Remember that the card has 8 edges (counting both sides) and will handle as many as 100 variables.

Place the master card over each of the data cards so that ¼ in. or more of the edge is showing. Put a mark on this exposed edge to indicate the level of each input variable for that particular card. Be sure that edges of the master card line up with the data card so that all code marks will register. A felt-pointed marking pen gives the most visible mark but an ordinary pen can be used when space is limited. When there are a large number of variables, different color code marks will be useful to distinguish between different sets of variables.

With the coded cards, data can be analyzed visually. Choose one of the listed output variables and arrange the cards in order of increasing output, smallest value on top. Ties should be ranked in random order. Now flex the cards back and forth to skew the deck and expose the code marks. This will give a plot of each input on that edge vs the chosen output. Notice, however, that the abscissa is not calibrated linearly because the cards were sorted only in order of increasing output—with no attention to the spread between output values on adjacent cards. The magnitude of the output value has been lost.

Strong effects mask minor ones

Scan each of the edgegraphs to discover which variables, if any, are related to the increasing output. Those input variables of interest should be replotted on ordinary graph paper to show the true relation to the magnitudes of the output. Also check to be certain the relationship between these input variables and other input variables is truly random. This can be done by arranging the cards according to increasing value of one input, and then examining the other input edgegraphs. A non-random relationship indicates data were not collected randomly. Such data are suspect and there is a serious risk of misinterpretation.

When an edgegraph shows one input that has a strong relationship with the output, there is possibility that this major effect is masking the effects of other inputs. Rather than rerun the experiment with this variable held constant, it is more practical to remove its effect by simply resorting the cards.

The mathematics are not difficult. Just correct the output—to the value that would have resulted if the offending variable had been constant (the method described in the example). If there are any strong relationships between the corrected output and the remaining inputs, these effects can be removed in the same way. You can repeat the procedure until no further strong effects are evident.

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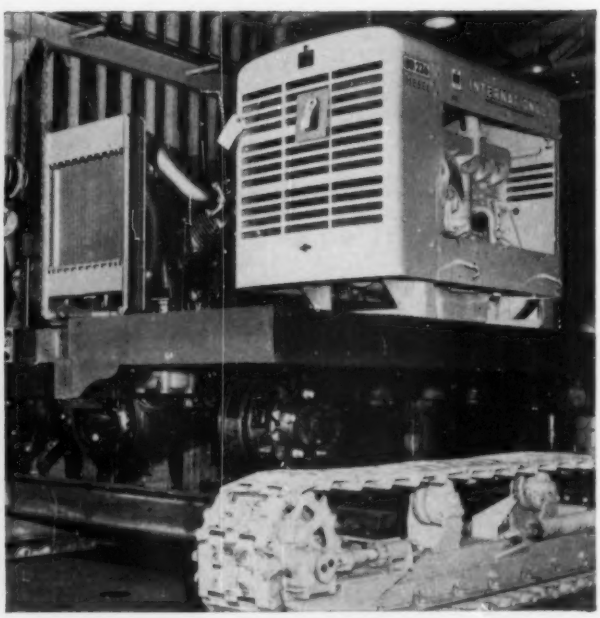

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In today's competitive market, designers are vitally interested in customer preference. That's why so many engineers insist on International. When you're ready to specify power, call International for complete product information and installation assistance. See how easy it is to design Sales Power into your equipment.

INTERNATIONAL®
ENGINES

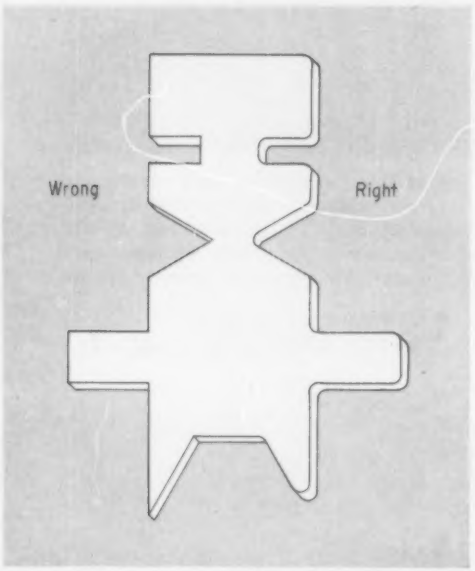
International Harvester Co.,
180 North Michigan Ave., Chicago 1, Ill.
A COMPLETE POWER PACKAGE

CIRCLE 49 ON READER SERVICE CARD

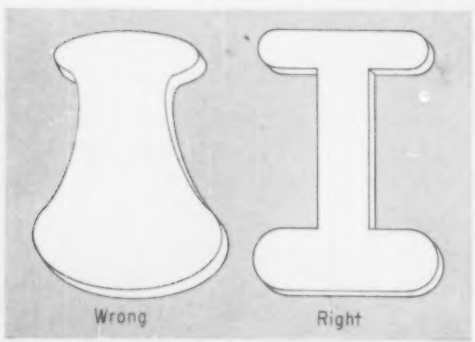
GROUND RULES for DESIGNING

Here's how to improve performance of parts; yet costs of initial tooling and tooling maintenance are less.

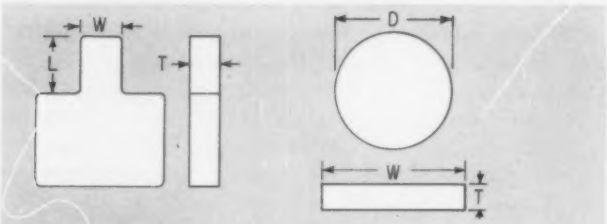
FEDERICO STRASSER
Mankowitz & Strasser
Santiago, Chile



1
ROUND OFF sharp corners, especially on acute angles. Do the same for slots and tabs, and make them wide. Preferred shape of slot is triangular.



2
STRAIGHT LINES are cheaper than curves. Make this change if redesigned part will still work.

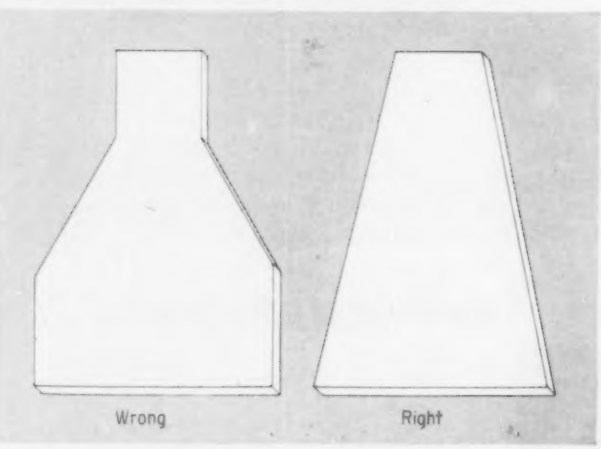


HOW TO FIGURE DIMENSIONS

TABS
Length $L \leqq 5W$.
Width $W \geqq 3T$, when $L \geqq 2T$.
Width $W \geqq 2T$, when $L < 2T$. Width should never be less than $\frac{1}{16}$ in. Cut minimum width 25 to 50% for aluminum or magnesium parts.

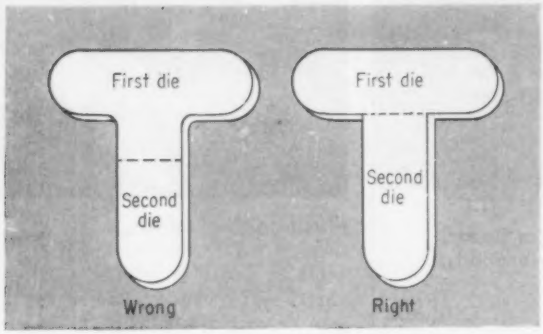
RADII
Radius $r \geqq 2T$ and at least 0.040 in. On same piece make all radii the same dimension.

LONG, NARROW PIECES
Make these by flattening wire. For a flat piece with width W and thickness T, diameter of wire $D = \sqrt{1.27WT}$.

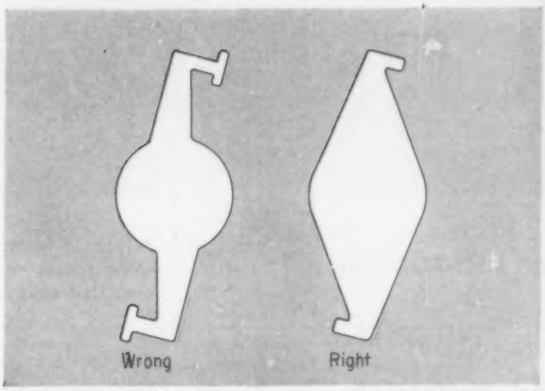


3
ELIMINATE unnecessary detail. Simplify shape of blank to cut cost of making tools.

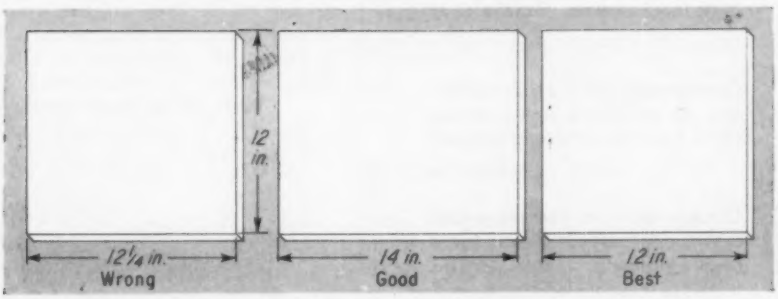
SHEETMETAL STAMPINGS



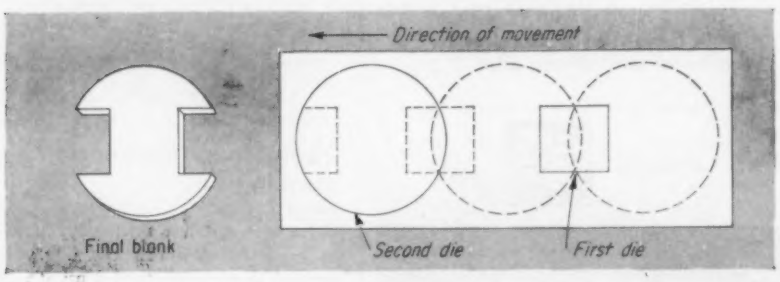
4
SIMPLER DESIGNS cost less. Sacrificing radii at two corners allows use of cheaper die for top of the T.



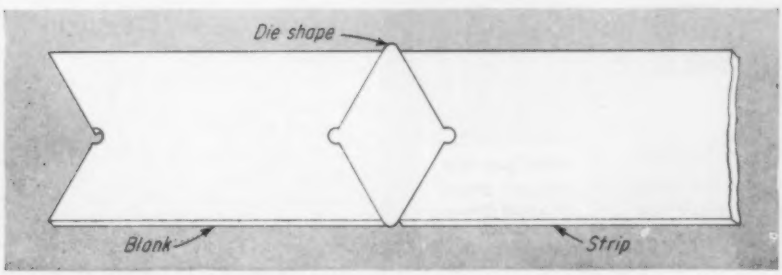
5
ADDED STRENGTH costs less with this part. Die is simpler; extra material comes from what would be scrap.



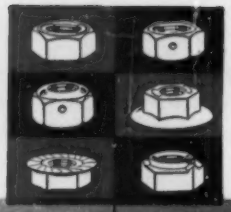
6
ASSEMBLY IS EASY when correct position is obvious. Square is best because it fits correctly in any position. Small difference in dimensions of first part makes quick recognition difficult.



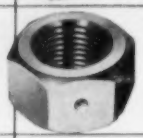
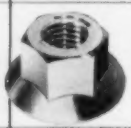
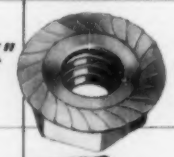
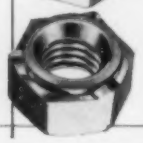
7
TWO DIES, working in two steps, do the job of one that would have been complicated.



8
SCRAP, INSTEAD OF BLANK, is punched out by die. Tool doesn't have sharp corners and acute angles, which would make machining, heat-treating and operation more costly.

One  of these
CAN IMPROVE YOUR PRODUCT . . .

SIX GREAT
MACLEAN-FOGG
LOCK NUTS

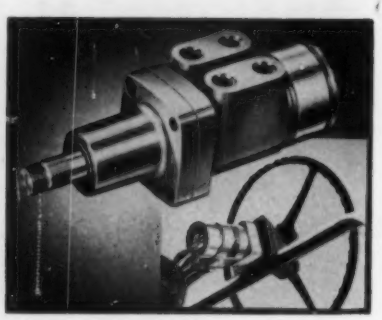
MF **UNI-TORQUE**		A free starter with lock at the top. Withstands severe vibrations. Cuts assembly time.
MF **TWO-WAY**		The Lock's in the center of nut. Can be applied from either end. Permits bolt end to be flush with, or below, top of nut.
MF OPEN END **CAP NUT**		Has two-way center-of-nut lock. Used on furniture, appliances, toys, lawn mowers, tools, etc.
MF UNI-TORQUE **FLANGE NUT**		Combination lock nut and washer. Use on oversized holes; where extra bearing surface is needed.
MF **"WHIZ-LOCK"** FLANGE NUT		This one spins on. Serrations take a firm grip on work. Break loose torque higher than seated torque.
MF PILOT TYPE **WELD NUT**		You can have it with or without lock. Simplifies assemblies by means of self-locating pilot.

CIRCLE NUMBER FOR ILLUSTRATED CATALOG

MAC LEAN-FOGG
MF LOCK NUTS

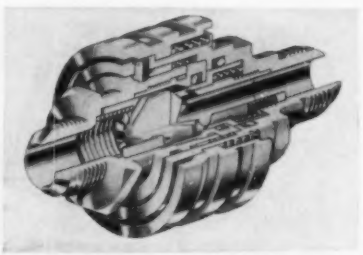
MacLean-Fogg Lock Nut Company
5535 N. WOLCOTT AVENUE
CHICAGO 40, ILLINOIS

Need Lock Nut Advice? Phone ED 4-8420 (Chicago) Collect.



Fluid-control device . . .
measures and delivers fluid to remote axle system at a rate proportional to steering wheel's rpm, eliminating mechanical linkage. Delivery is controlled by diverting fluid from an open center circuit to a meter which repositions control valve sleeve to correspond with needed motion. Low pressure drop across meter is said to greatly reduce hydraulic slip. In the event of power failure or during engine shutoff, meter automatically becomes a rotary hand pump, coupled in series with load, so that steering can be done manually. Said to be able to reduce steering system weight by 75 to 80%. Char-Lynn Co, Dept P, 2843 26th Ave S, Minneapolis 2.

Circle 300 on Reader Service Card



½-in. quick-disconnect coupling . . .
allows less than 2.2 cc fluid to escape on disconnect and less than 0.10 cu in. air to be included during coupling. Shows pressure drop of less than 8 psi at 6 gpm, using MIL-0-5606 fluid. Flush-face coupling (also available as ¼-, ⅜-, ⅝-, ¾-, 1- and 1¼-in. models) locks tight with an audible signal when spring-loaded socket collar engages locking pins. Ports uncover when socket and nipple are fully sealed, and all entrapped air is forced out before flow takes place. All action is straight line axial, making coupling accessible in limited installation areas. Sizes ¼ through 1 in. are rated at 4500 psi, burst at 7500 psi. Size 1¼ in. is rated at 900 psi, burst at 1500 psi. Fluids handled include MIL-

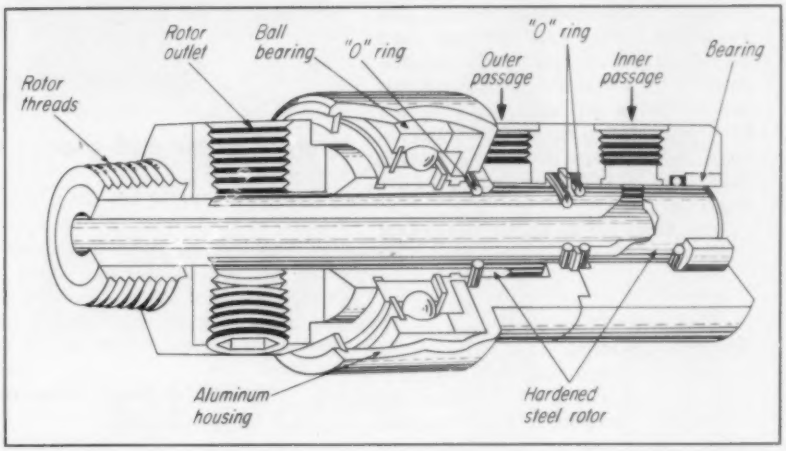
0-5606, MIL-C-5502 and 7808 hydraulics; exotic power; and others to 3000 psi and up. From stock as of Feb 1 at $32 to $120. **Jack & Heintz Inc, PO Box 6719, Cleveland 1.**

Circle 301 on Reader Service Card

Stabilized polypropylene tubing . . .

can be used at temperatures up to 300 F and working pressures to 450 psi. Reportedly lasts 30 to 50 times longer than nylon tubing at elevated temperatures and outlasts other thermoplastic tubing because of no gradual change in physical properties under adverse conditions. Resists corrosion and is not affected by boiling sulfuric or concentrated hydrochloric acids and saline solutions. Has nearly zero water absorption and low mineral and vegetable oil absorption. Available in ⅛- to ⅜-in. OD sizes. Smallest size furnished in 1000-ft spools; other sizes in 500-ft spools in natural or black. **Imperial-Eastman Corp, 6300 W Howard St, Chicago 48.**

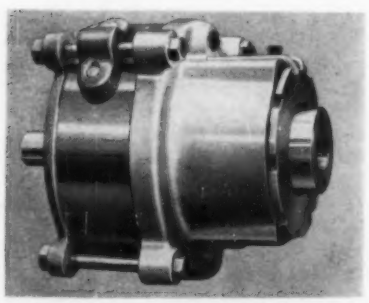
Circle 302 on Reader Service Card



Double-passage rotating union . . .

operates at 150-psi air pressure, 1000-psi hydraulic oil pressure and at max 200-rpm rotational shaft speed. Handles two different mediums or the same medium through two different passages. Suitable for equipment that requires double passage conveyance of air, oil or other materials and for rotating cylinders that call for pressure to either side of a piston. Ball and sleeve bearings eliminate radial load on unit's O-ring, so that it is not required to act as a bearing. From stock at $80. **Deublin Co, 1919 Stanley St, Northbrook, Ill.**

Circle 305 on Reader Service Card



Shaft-mounted gear reducer

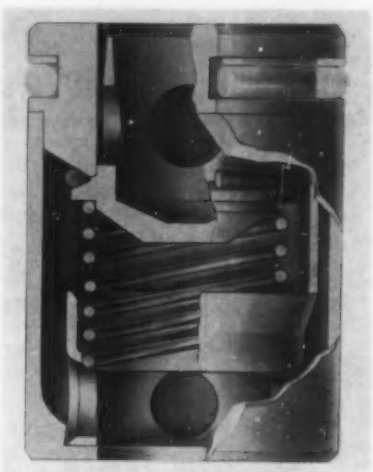
has ratio range from 3½:1 to 36:1 and hp range from 4 to 30. Available in either steel or aluminum housing. **Crichton Co, Johnstown, Penna.**

Circle 303 on Reader Service Card

Bronze-bushed idlers . . .

from stock in 14 standard sizes, have 1-in. bores and sprockets in Nos. 35 through 80 roller chains, both single and double widths. Pulleys, in 1-, 2- and 3-in. face widths with 4-in. dia, are used with V-, flat-, and timing-belt drives. **Brewer Machine & Gear Co, 1441 N 2nd St, St Louis.**

Circle 306 on Reader Service Card



Cartridge checkvalve . . .

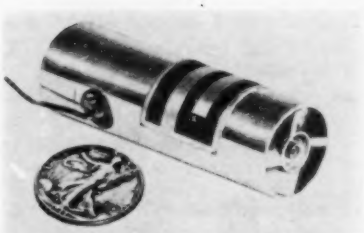
can be placed in a single bored hole, eliminating bulky, complicated piping arrangements. Available in steel or aluminum in sizes from ⅛ to ¾ in. Operates at pressures to 5000 psi. **Circle Seal Products Co Inc, 2181 E Foothill Blvd, Pasadena, Calif.**

Circle 308 on Reader Service Card

High-impact solenoid valves . . .

hold operating position until energized even when subjected to 400 g. Two-position, direct-acting units are available for 4000-psi service with two solenoids or for 2000-psi service with one solenoid and spring return. Seals, dynamically loaded to reduce torque, wipe sealing surfaces clean as they slide across disk. **Republic Mfg Co, 15655 Brookpark Rd, Cleveland 35.**

Circle 304 on Reader Service Card



Miniature dc-powered blower . . .

moves 10 cfm air against 0.3 in. water back-pressure. Tube axial unit measures 1⅛-in. dia x 3¼ in. long and weighs 3.5 oz. Operates on 27 v dc. **Globe Industries Inc, 1784 Stanley Ave, Dayton 4, Ohio.**

Circle 307 on Reader Service Card

continued on page 54

Constructional alloy steel . . .

in thicknesses from ⅜ to 1 in. inclusive, is reported to be priced "significantly less" than similar steel on market because of chemical composition differences. Has 100,000-psi min yield strength and 115,000 to 135,000-psi tensile strength. Available in quenched and tempered bars and plates, in all widths, lengths and qualities (including flange, firebox and aircraft) currently furnished. **United States Steel Corp, 525 William Penn Pl, Pittsburgh 30.**

Circle 309 on Reader Service Card

Speed reducers . . .

are available with normal double-reduction gear train and with double-reduction plus duplex gear arrangement. Latter uses two primary gears and two final pinions to share load from high-speed pinion to slow-speed output gear. Driven by separate, direct-connected motor. Capacities range from ¼ to 75 hp with ratios from 5.00 to 47.4. **Electrical Motors Inc, Box 2058, Terminal Annex, Los Angeles 54.**

Circle 310 on Reader Service Card

Teflon hose . . .

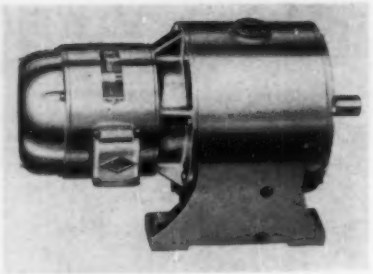
with stainless steel wire braiding, withstands temperatures from —65 to 450 F. Ordinary hand tools can assemble hose and reusable, cadmium-plated brass NPT male fittings. Sizes range from ⅛ to 1¼-in. ID. **Anaconda Metal Hose, PO Box 791, Waterbury 20, Conn.**

Circle 311 on Reader Service Card

Stacking manifold air valve . . .

can be lifted from manifold plate by removing four bolts. Replacement valve then is bolted down, putting control system back into operation without disturbing plumbing or wiring. Valve solenoids, either single or double, plug into plate's electrical connections. Manifold stack accepts 2- and 3-position, and 3- and 4-way valves in ¼-, ⅜- and modified ½-in. sizes. Additional valves can be added. From stock as of Feb 1 at $55 to $70. **Beckett-Harcum Co, 985 W Locust St, Wilmington, Ohio.**

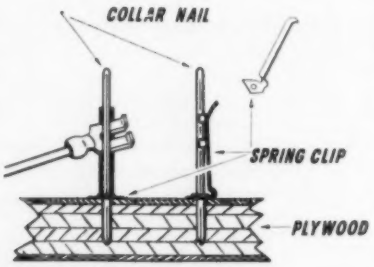
Circle 312 on Reader Service Card



Integral motor and gear reducer . . .

is rated from ½ to 50 hp. Drive motors available as wound-rotor slip-ring, squirrel-cage, crane-hoist or torque in dripproof or totally enclosed construction. Gear reducer drops rated motor speeds to 520 rpm through 9-rpm-output shaft speeds. From stock. **Reuland Electric Co, Alhambra, Calif.**

Circle 313 on Reader Service Card



TYPICAL USE OF SPRING CLIP

Conductor spring clip . . .

approx 1⅛ in. high, holds lugs or wire in place and allows them to be removed without damage. Top of clip is held taut against collar nail when nail is driven through hole in clip. Spring action holds spade in position of hardened spring steel. **Stevens-Cress Co, Cresskill, NJ.**

Circle 314 on Reader Service Card

Miniature lighted billboard . . .

measuring 1.124 x 0.312 in., is rated at 0.04 amp at 28 v; 0.08 amp at 14 v; or 0.2 amp at 6 v. Legend, engraved on inside of lens, is readable only when indicator is lit. Lenses are available in four colors. Lamps are replaceable from front of panel. **Control Switch Div, Controls Company of America, Folcroft, Penna.**

Circle 315 on Reader Service Card

Electronic counter . . .

accepts impulses of 120 microsec. Uses photoelectric pickup for sensing and actuation, and "pulse stretching" circuit for high speed and accuracy. Has 3000-cpm counting rate, rapid reset and is said to last for over one hundred million counts. From stock at approximately $165. **Veeder-Root Inc, Electronic Controls Div, Danvers, Mass.**

Circle 316 on Reader Service Card

Miniature plug-in amplifier . . .

functions with either negative or positive gain and is suitable as an instrument preamplifier or in data-handling systems. Has no choppers or tubes. Input resistance is 20 k and output current capability is 1 ma at 10 v. Drift is less than 1 milliv over a 45-F ambient change, less than 10 microv at constant temperature over 8-hr period. Linearity is within 0.1% in an output swing of ±10 v. Companion power booster, which can be mounted in tandem or alongside amplifier, has an output current of 100 ma at ±10 v. Amplifier is priced at $195; power booster at $75. **Ridgefield Instrument Group, Div Schlumberger Corp, Ridgefield, Conn.**

Circle 317 on Reader Service Card

Precision photoetching . . .

produces stress-free metal parts, thinner than 0.001 in.; burr-free square-edge parts; and quantities of intricate small parts that would normally require hand work—all within ±0.005-in. tolerances. Handles stocks of more than 0.025 in. thick. **Eburn Industrial Research Corp, 349 Lincoln St, Hingham, Mass.**

Circle 318 on Reader Service Card

Power takeoff assembly . . .

comprising emergency brake, speedometer drive and output flanges, weighs 175 lb and is said to contain half the parts previously required. Suitable for trucks with 1¾-in. dia or smaller output shaft on main transmission. Output ratio is 100% of transmission output speed. All transmission speeds, including reverse, are avail-

continued on page 55

able through assembly. Can be used as top, right-hand-side, or left-hand-side mount. Tapered roller bearings permit mounting pulley or sprocket directly on shaft. Chelsea Products Inc, Chelsea, Mich.

Circle 319 on Reader Service Card

Beam compass holder for tape pen . . .

is used to draw precision circles and arcs with radii of 1 to 9 in. If longer radii are needed, 9¾-in. sections can be coupled to basic beam. Priced at $9.50. Extra sections, $2 each. Chart-Pak Inc, 1 River Rd, Leeds, Mass.

Circle 320 on Reader Service Card

Digital vibration analyzer . . .

performs on-line spectral density analysis of random or periodic signals representing strain, vibration, pressure fluctuation, etc. Spectral-energy distribution is over a bandwidth of 5000 cps with a resolution of 50 cps. Distributed energy is then encoded at a rate of 5000 readings per sec and placed on ½-in. magnetic tape for entry into computing equipment. Entire spectrum is swept and encoded every 20 millisec or on command. Tape can reproduce spectrum, sec by sec, in tabulated or plotted form. Unit—60-in. high and 18 in. deep—can be purchased or leased, with delivery in 120 days. Communications Control Corp, 14707 Keswick St, Van Nuys, Calif.

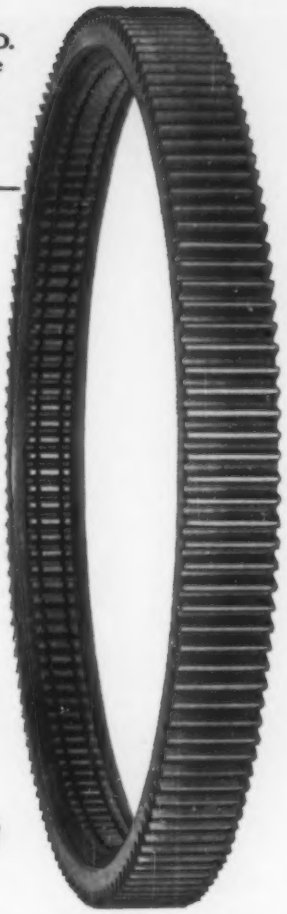
Circle 321 on Reader Service Card

Plastic templets . . .

are suitable for drawing wide range of standard symbols and figures, circles, squares, triangles and ellipses—all in graduated sizes and scales. Eighteen individual models include special templets for architectural, electrical and electronic, and ductwork drawings. Keuffel & Esser Co, Adams & 3rd Sts, Hoboken, NJ.

Circle 322 on Reader Service Card

Snap-ring grooves in this 12" O. D. thin-section *Reduction Drive Gear* are machined before carborizing and hardening. Both spline and gear teeth are ground and held to .001" excentricity after hardening the entire gear.



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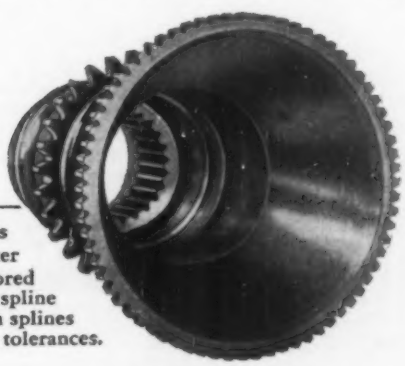
Men who *know* will tell you that custom precision gears made by Perkins can eliminate many design, production and maintenance headaches — literally help you drive for better profits. When you want precision gears in experimental or production quantities, chances are you'll save time and money by checking with Perkins first. What is your gear problem today?

This Handy Gear Calculator, easy to use, saves time. *Folder* illustrating Perkins custom precision gears and facilities offers information. Both yours on request.



Most machining operations on this *Drive Gear Shaft* are performed after localized hardening with the cored areas at Rockwell C42. External spline and gear teeth are ground with splines held to precision tolerances.

Designed to sense extremely low speed rotary or linear motion for both industrial and O.E.M. applications

The GAYLORD MICRO-MOTION DETECTOR will sense zero and low speed rotary motion (or low speed linear motion converted to rotary motion) over an infinite number of positions in 360° of rotation. It will also sense direction of motion and a change in direction of motion. It will operate at extremely low speeds, but can be driven at considerately higher speeds. No resetting is required. Operates over a wide temperature range. Extremely small size and light weight of the GAYLORD MICRO-MOTION DETECTOR (2" wide x 2⅝" high; 3 ounces) makes it useful for an almost unlimited range of industrial and O.E.M. applications.

For engineering data and demonstration, visit the
GAYLORD CONTROLS EXHIBIT
(Booth 627) at
SOCIETY OF AUTOMOTIVE ENGINEERS
COBO HALL, DETROIT, MICHIGAN
INTERNATIONAL CONGRESS & EXPOSITION
JANUARY 9-13, 1961
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GC GAYLORD CONTROLS

A DIVISION OF GAYLORD PRODUCTS INCORPORATED · 1918 S. PRAIRIE AVE., CHICAGO, ILLINOIS

CIRCLE 56 ON READER SERVICE CARD

DRILLUNIT *Solves* Drilling Problems

Flexible-Dependable

Self contained —Compact,—can be mounted in any position or angle, in a small area.

Single or Multiple spindle applications, can be adapted for Drilling, Reaming, Chamfering, Boring, Counter Boring and Spot Facing.

Stroke and feed variations obtainable without changes in the unit.—Step feed drilling possible with slight modification.

9" and 12" stroke —up to 5 H.P.

Standard Models Available from Stock

Write for literature.

DRILLUNIT, INC.
HYDRAULIC DRILL UNITS
3267 Wight Street • Detroit 7, Michigan

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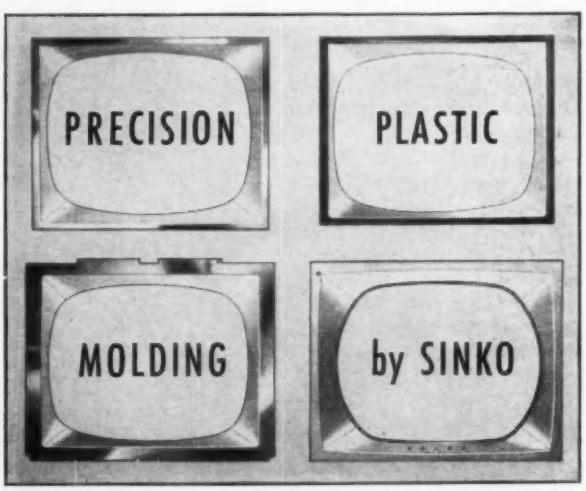

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DESIGN LITERATURE

The Crisis We Face: Automation and the Cold War

GEORGE STEELE and PAUL KIRCHER. McGraw-Hill Book Co Inc, 330 W 42nd St, NY 36. 5½ x 8¼, 220 pp. $4.95.

As this country moves into automatic control of defense and production we face a crisis of computer-system overcomplexity and lack of product reliability. In *The Crisis We Face* the authors make out a disturbing and, where they analyze our defense, a chilling case for a drastic revision of the present trend in automatic control.

Of what point, for example, is a hypercomplex missile-computer system that occupies several hundred square feet of floor space, when adequate guidance could actually be accomplished by a pocket-size tape recorder as, apparently, the Russians have demonstrated? Since one of the authors George Steele, is a private computer consultant who speaks with convincing authority, his question must be considered valid in spite of the incredible inferences it raises. One answer is that it is more profitable for a company to pyramid computers in the name of ultra-accuracy. This answer has weight because Paul Kircher, the other author of this book, is associate professor of business administration at UCLA.

Again, how ridiculous is a vast complex of computer systems when the failure of one valve, relay or circuit breaker, etc., could shut down the entire system. Often these components are spliced into the system at a low engineering or even drafting level. Worse, many are made by subcontractors who have little liaison with the main unit.

The book also indicts top management in industry, defense and government for an inability to understand the broader implications of today's scientific developments.

An all-too-plausible review of what could happen in an actual attack upon this country is also made—our vaunted missile and SAC strength is shown to be so vulnerable to radiation and blast effects that it would be reduced to virtual impotence.

The only trouble with the book is that to appreciate the full significance of much of it, some degree of familiarity with the technical problems involved is really necessary. The ones who have brought about this crisis—nontechnical management and military "experts"—will be the very ones on whom much of the book would be lost!

Nevertheless, for engineers who can face it this book gives a sobering view of the direction their labors are taking, revealing the utmost of futile misguidance. For those who guide our destinies the reading of this book would be a statesmanly act. —DCG

Symposium on Hydraulic Fluids

American Society for Testing Materials, 1916 Race St, Philadelphia 3. 6 x 9, 102 pp. $3.75; members, $3.

The papers in this Symposium on Hydraulics were presented during two sessions on Oct 13, '59, at the Third Pacific Area National Meeting of the Society, San Francisco. The symposium was sponsored by Technical Committee N on Hydraulic Fluids of Committee D-2 on Petroleum Products and Lubricants. Covered are: problems and trends in the use of hydraulic fluids, spray-flammability test for hydraulic fluids, hydraulic fluids for use in high-pressure shipboard equipment, high-performance fluids for military aircraft and industrial applications, emulsion-type fire-resistant industrial hydraulic fluids, development and testing of aircraft hydraulic fluids.

Electrical Noise

W R BENNETT, Bell Telephone Laboratories. McGraw-Hill Book Co Inc, 330 W 42nd Street, New York 36. 6 x 9, 288 pp. $10.

Describes in qualitative terms the physical nature of various important noise sources, including thermal agitation or resistance noise, shot noise in vacuum tubes and semiconductor junctions, noise from spontaneous emission of electromagnetic radiation, and noise in gas discharges. Fundamentals needed for analyzing basic sources of noise are covered, and methods of measurement and design are stressed. A discussion of the relation of signal and noise in communication systems of various types is in-

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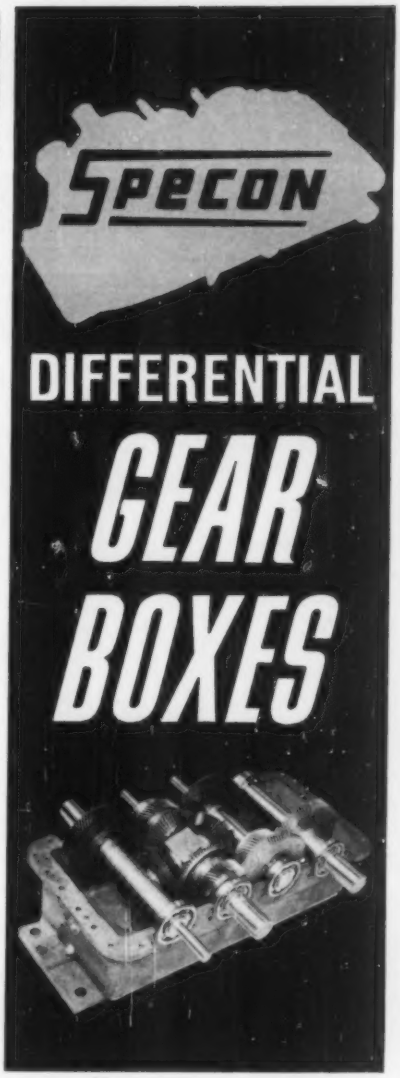

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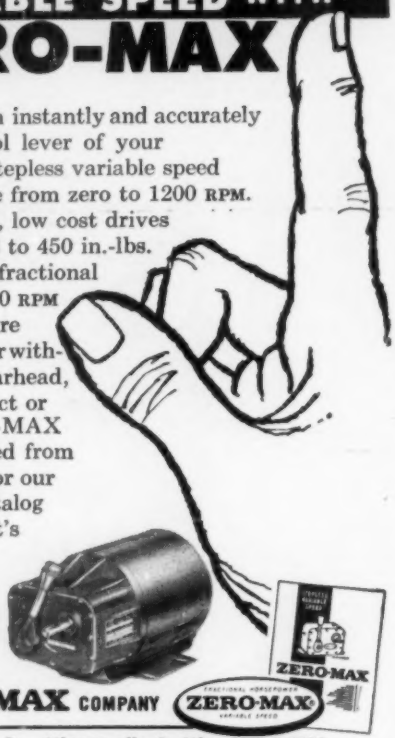

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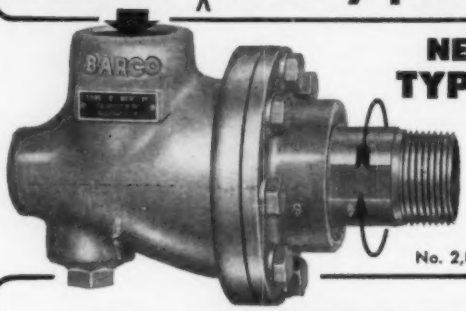

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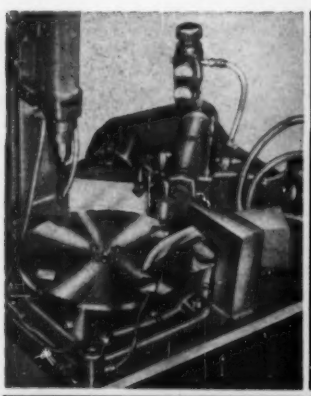

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cluded. Covered are transistors, masers, and parametric amplifiers, junction diodes, gas discharge tubes, klystrons, traveling-wave amplifiers and nonlinear reactive amplifiers.

Differential Effects of Speed and Load Stress on Task Performance

PB 161482. Gabriel Jeantheau. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8½ x 11, 13 pp. 50¢.

This study investigated effects of speed-load stress (input rate and variety) on performance in an information-processing task requiring discrimination of pairs of identical symbols within matrices of three levels of word length and five levels of presentation rate. Error scores and a derived information measure were used to assess performance. Results indicated that increases in both speed and load seriously impair performance.

Elements of Maser Theory

ARTHUR A VUYLSTEKE, General Motors Corp. D Van Nostrand Co Inc, Princeton, NJ. 6¼ x 9¼, 362 pp. $9.50.

The theory of maser operation covered represents an instructive application of the quantum theory, statistical mechanics and the interplay between the two. Fundamentals and applications are discussed at length. Although extensively mathematical, the book is also self-contained, and includes all of the concepts and mathematical apparatus necessary to an understanding of the basic subject matter. Covered are Bohr quantum theory, statistical mechanics, quantum mechanics and radiation theory.

ABSTRACTS FROM THE LITERATURE

Efficiency of Antifriction Bearings

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continued on page 61

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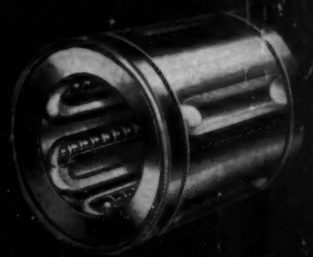

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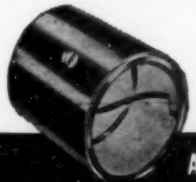

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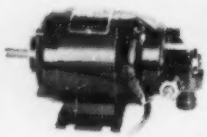

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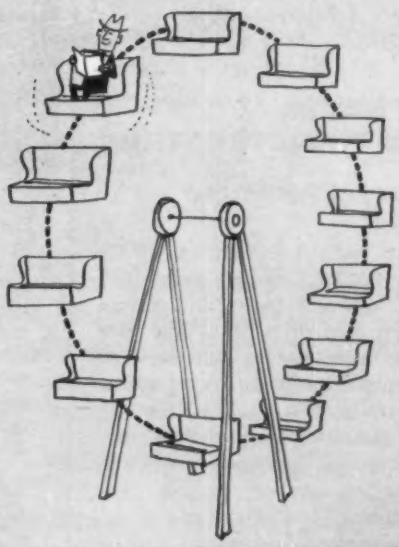

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where the angular range of the change of load direction does not exceed 90°).

"Increasing the Efficiency of Antifriction Bearings and Reducing Specific Metal Consumption," A M Kovalevskiy, Translation of Vestnik Mashinostroyeniya (USSR) '58 Vol 38, no 8, p 3-9. Available from Photoduplication Service, Publication Board Project, Library of Congress, Washington 25, DC.

Gas Bearing for Thrust Applications

This paper evaluates the self action developed by a nonpressurized parallel-surface gas-lubricated thrust bearing as a result of steady precession of the slider and applies these results to the bevel bearing introduced by the authors in an earlier paper.

"A Novel Form of Self-acting Gas-lubricated Thrust Bearings," Nahavandi, Westinghouse Electric Corp; Osterle, Carnegie Institute of Technology. American Society of Lubrication Engineers Paper No. 60 LC-13, 5 N Wabash Ave, Chicago 2.

Controlled-leakage Seals

Controlled-leakage pump seals were developed about ten years ago to meet special problems in closed cycles of high-pressure boiler-feed-pump stuffing boxes and boiler-circulating pumps. In high-pressure feed pumps, pressures and temperatures vary widely with changing station loads, so life of normally packed stuffing boxes was far from satisfactory. Constant maintenance—gland adjustment and packing replacement—resulted. In boiler-circulating pumps, the temperatures and pressures normally encountered often preclude packing of any sort. Today, controlled-leakage seals have broadened their applications, also taking in high-speed boiled-feed pumps at 5000 to 9000 rpm where packing's rubbing speeds would be prohibitively high, and some open-cycle boiler-feed-pump applications.

"Controlled-leakage Seal . . . One Answer to High-pressure Stuffingbox Problems," T W Edwards, Assistant Editor. Power, Nov '60, 330 W 42nd St, New York 36.

Lubricant Viscosity and Wear

This paper investigates the effect of lubricant composition on engine friction and connecting-rod-bearing wear. Special attention has been given to polymer-thickened oils, since these oils are characterized by shear-dependent viscosity and a simultaneous occurrence of viscous and elastic properties. The variables investigated in this study included lubricant viscosity, polymer type, and concentration.

"The Effect of Lubricant Viscosity and Composition on Engine Friction and Bearing Wear," E. H. Okrent, Esso Research and Engineering Co. American Society of Lubrication Engineers Paper 60 LC-8, 5 N Wabash Ave, Chicago 2.

"These drawings are all obsolete, Jenkins . . . you will have to tackle it from another angle . . ."

CATALOGS AND BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover.

PLASMA COATING—Technical bulletin, 12 pp. Reviews plasma-coating process, properties and uses of coatings. Lists 11 materials that can be plasma torch-sprayed, and their properties. Plasmatech Div, Valley Metallurgical Processing Co Inc, Essex, Conn.

Circle 350 on Reader Service Card

NYLON, TEFLON, EPOXY PARTS—Catalog, 24 pp. Gives specifications for more than 500 bobbin, washer and precision-made stock parts. Tabulates properties of nylon, Teflon and epoxy materials. Cosmo Plastics Co, 3239 W 14th St, Cleveland 9.

Circle 351 on Reader Service Card

TEMPERATURE CONTROLS—Catalog G-25, 4 pp. Explains operation of differential expansion type control, both electric and pneumatic. Illustrates and outlines specifications for 21 models. Burling Instrument Co, 16 River Rd, Chatham, NJ.

Circle 352 on Reader Service Card

BALANCED ROTARY RELAYS—Catalog 860, 28 pp. Contains environmental characteristics; electrical specifications and diagrams; and drawings of each header and enclosure style. Also covers electronic

continued on page 62

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time delays, constant pull-in relays, solid state modules and voltage sensors. Performance data traces operate and release times; shock vibration and related parameters, etc. Hi-G Inc, Bradley Field, Windsor Locks, Conn.

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WIDE-RANGE TEMP-CONVERSION CHART—Bulletin 10605, 8½ x 11-in. sheet. Converts from Kelvin, Rankin, Centigrade and Fahrenheit to any other scale. Range is from absolute zero to 16,000 C. Also shows boiling and melting points of metals and other elements. Rosemount Engineering Co, 4900 W 78th St, Minneapolis 24.

Circle 354 on Reader Service Card

PRINTED CIRCUIT CONNECTORS—Folder, 6 pp. Describes 1- and 2-piece connectors and contains line drawing of 5 types of snap-in contacts and connector housings. AMP Inc, Harrisburg, Penna.

Circle 355 on Reader Service Card

FILTER CARTRIDGES—Bulletin MW-100, 4 pp. Describes process by which separate filtering medium is interwoven with structural spiral windings on a perforated metal core. Discusses micron densities, structural strength and fluid compatibility. Cuno Engineering Corp, 80 S Vine St, Meriden, Conn.

Circle 356 on Reader Service Card

SILICON AND SELENIUM RECTIFIERS—Catalog 100, 8 pp. Tabulates electrical and mechanical specifications of 13 silicon types as well as dc current ratings and amperes of selenium power stacks and cartridge type rectifiers. Curves show forward current rating levels and derating for increased ambient temperatures. Semiconductor Div, Syntron Co, Homer City, Penna.

Circle 357 on Reader Service Card

"Don't worry about it. We all make mistakes now and then, you blithering idiot."

TIMESAVING IDEAS—Booklet, 34 pp. A compilation of 59 illustrated suggestions for the draftsman and engineer, ranging from finding foci of any ellipse to removing dust from pencil tips. Frederick Post Co, P O Box 803, Chicago 90.

Circle 358 on Reader Service Card

POTENTIOMETERS—Brochure 6, 4 pp. Covers resistance ranges, end settings, tolerances, power rating, operating temperature, size and price of 13 leadscrew- and wormgear-actuated models. Contains cutaway drawings of four basic types. Bourns Inc, Trimpot Div, 6135 Magnolia Ave, Riverside, Calif.

Circle 359 on Reader Service Card

PACKAGED CONTROLS — Bulletin GEA-6334A, 8 pp. Describes and illustrates panels tailored for specific control needs and devices used, including contactors, starters, relays, switches, timers, terminal boards and pushbuttons. General Electric Co, Schenectady 5.

Circle 360 on Reader Service Card

HYDRAULIC SYSTEMS — Bulletin I-5802, 6 pp. Discusses advantages of hydraulics in process control and illustrates typical packaged hydraulic systems and installations. Vickers Inc, Div Sperry Rand Corp, Detroit 32.

Circle 361 on Reader Service Card

WATER-SYSTEM FITTINGS—Catalog, approx 48 pp. Illustrates and gives sizes and prices of steel, brass, aluminum and plastic fittings for flexible plastic pipe. Also covers well seals and caps, foot and check valves, water hammer eliminators, motor pump supports, torque resistors and other equipment. Campbell Mfg Co, Boyertown, Penna.

Circle 362 on Reader Service Card

LETTERING SET—Pocket-size folder, 6 pp. Illustrates seven-piece set and gives samples of letter faces and sizes that can be drawn. Keuffel and Esser Co, 3rd & Adams Sts, Hoboken, NJ.

Circle 363 on Reader Service Card

SPRING AND DIAPHRAGM ACTUATORS—Bulletin B-1020-7, 4 pp. Shows actuators in typical combinations with butterfly, adjustable port and burner valves. Contains specifications, operating characteristics and dimensional drawings, Conoflow Corp, 2100 Arch St, Philadelphia 3.

Circle 364 on Reader Service Card

PRODUCT, SYSTEMS RELIABILITY—Booklet, 16 pp. Solving reliability problems is described in terms of management planning and organization, technical analysis and operation, and education and training. Systems Engineering Div, Planning Research Corp, 1333 Westwood Blvd, Los Angeles 24.

Circle 365 on Reader Service Card

RESEARCH AND DEVELOPMENT FACILITIES—Brochure, 20 pp. Discusses physical equipment and facilities for prototype fabrication (from design to production), as well as limited and mass production of mechanical, electromechanical and electronics components, assemblies and systems. Singer-Bridgeport, 915 Pembroke St, Bridgeport 8, Conn.

Circle 366 on Reader Service Card

REPRINTS

Reprints currently available without charge are listed on the Reader Service Card bound in this issue. Single copy free; quantity prices on request.

The following special reports are available as long as the supply lasts, from Reader Service Dept., Product Engineering, 330 W 42nd St, New York 36. Please enclose remittance with order we pay postage.

R77—The New Mathematics $2

Combined reprint of 18 articles with coverage in depth on the latest math tools of systems engineering, 64 p.

R48—Reinforced Plastic Parts $2

Combined reprints of 11 articles giving design data on the seven processes for commercial parts, 64 p.

R69—Human Engineering $1.50

Series of 14 articles with design data on man-machine problems and human dimensions; plus bibliography, 44 p.

R76—Creativity $1

Combined reprint of 10 articles on the facts behind the fad, 32 p.

R66—The European Engineer Talks $1

The challenge to American proficiency in design from interviews with technical directors in six countries, 24 p.

R16—Plate Cam Design $1

Series of 7 articles with complete design data; curve blending and profile synthesis to reduce inertia, 48 p.

R65—Reading, Writing, Reporting $1

Combined reprint of: 5 steps to faster reading: 8 steps to better writing: 7 steps to better reporting, 24 p.

R46—Manual of Reliability 50¢

How to design for reliability, human factors, statistical tools; implementing the program, 32 p.

R78—Ball Bearings 50¢

Performance of 50 commercial and precision types tabulated and compared, 16 p.

R41—Design by Digital Computers 50¢

How to choose and operate desk-size problem solvers, 12 p.

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IT TAKES RUGGED PUMPS TO SPRAY HOT ASPHALT

ABOVE—Newest Littleford "Spray Master" DeLuxe Asphalt Distributor includes two Viking Pumps.

LEFT—400 G.P.M. heavy duty Viking Pump delivers hot asphalt under positive pressure to spray bar.

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CIRCLE 209 ON READER SERVICE CARD

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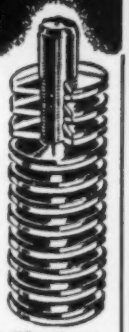

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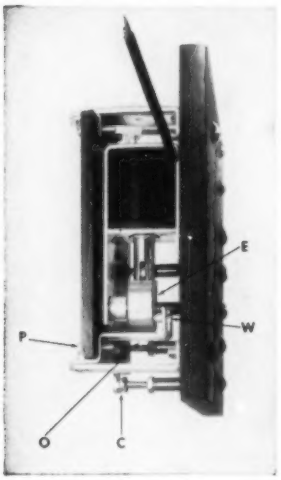
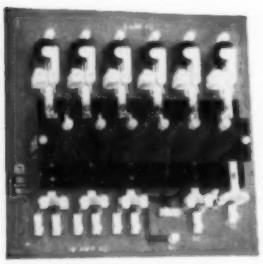


The Unique ASCO Mechanically Held Movement

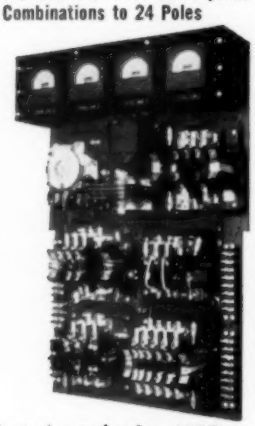
When the solenoid is energized, eccentric cam (E) is rotated. Weight drive pin (W) causes movement of operating lever (O). Lever (O) (connected to the contact finger block) rotates on pivot pin (P) and contacts such as (C) are opened or closed.

Note that with the solenoid de-energized, the entire mechanism is firmly locked in place by the angular position of the linkages—no springs, latches, or semi-permanent magnets are required!

ASCO Mechanically Held Relays A-C and D-C . . . to 25 Amperes Combinations to 24 Poles



Special ASCO Relay with 6 D-C Poles for 600 volts, 3 A-C Poles for 230 volts and 125 volts D-C control. Note Blow-outs on D-C Poles.



Control panel using ASCO Mechanically Held A-C Relays (Bulletin 1256-168). Notice multiple pole and double throw arrangements.

ASCO Power Driven Relays with No Springs or Latches:

- Provide higher contact pressures
- Minimize the possibility of contact welding
- Insure positive operation

Design simplicity is provided in ASCO Mechanically Held Relays through use of a single solenoid coil mechanism. The coil is momentarily energized during the instant of operation only. This momentary surge of power electrically operates the relay to *open and close* contacts; thus the relay is power driven in both directions, with no dependency on springs or gravity for operating and mechanically holding the contacts.

FEATURES

• No A-C hum or chatter • Operate in any position • Compact construction permits mounting on metal surfaces or panelboards • Operated by single-coil mechanism—positive in each direction • Silver contacts rigidly locked open or closed by angular relation of linkages—no delicate hooks or latches • Signal lamps require no extra contacts or control wires • Enclosed rating same as open rating due to liberal design and momentary mechanism without coil losses • All parts finished in cadmium plate or black to present good appearance and to match larger ASCO Switches.

APPLICATION

ASCO Mechanically Held Relays are used for automatic or remote control where A-C hum or chatter is objectionable, where coil loss is undesirable or where relays must not change position when the control circuit fails (low voltage release). ASCO Mechanically Held Relays are often used for master control of other control equipment, to prevent loss of voltage or control failure. These relays are frequently used for electric heaters, lighting, and similar applications.

Mechanically Held Relays are only part of the complete line of Relays made by ASCO. Our Catalog 57-S4 lists:

MAGNETICALLY HELD RELAYS
A-C or D-C . . . Normally Open . . . Normally Closed . . . Double Throw

ASCO Magnetically Held Relays use a physical arrangement which parallels that of ASCO Rocker Type Mechanically Held Relays. Since the two types are similar in appearance, they help to increase the attractiveness of control panels, at the same time offering interchangeability of contacts.

SPECIALIZED RELAYS

. . . Reverse Current
. . . Time Delay
. . . Brake Winding Time Delay
. . . Close Differential
(Voltage and Current Types)
. . . Current Type, Welding
. . . Electronic
. . . Modified Arrangements

Write for your copy of "Relays by ASCO"—Catalog 57-S4

ASCO Electromagnetic Control

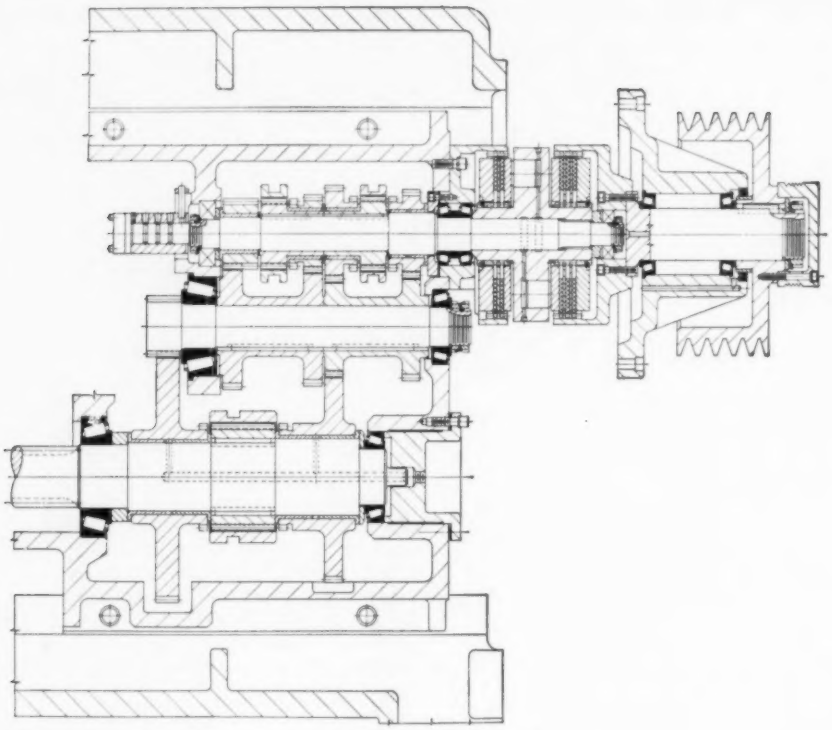
Automatic Switch Co. 54-G HANOVER RD., FLORHAM PARK, N. J., FRONTIER 7-4600

AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

ASCO®

CIRCLE 202 ON READER SERVICE CARD

Bullard fully powered vertical turret lathe uses Timken® bearings to maximize production



When designing their Dynatrol® Vertical Turret Lathe, Bullard engineers' aim was to increase machine speed and output economically. Dynatrol provides single lever or remote control of all head motions, traverse and feed engagement. And Timken® tapered roller bearings at vital points—table radial position, headstock, clutch shaft, input pulley, rail raising bracket—provide the load-carrying capacity under varying loads and speeds that assures maximum production. Their taper lets Timken bearings take *any* combination of radial and thrust loads. And precision manufacture of Timken bearings assures high precision in the machine.

ENGINEERING SERVICE THAT SAVES YOU TIME AND MONEY. Working with you at the design stage, our sales engineers can often solve your bearing problems on the spot. From the wide range of Timken bearing sizes, types and precisions they can help you select the Timken bearings to give you the maximum in efficient, economical design engineering.

Industry rolls on

TIMKEN®

tapered roller bearings

The Timken Roller Bearing Company, Canton 6, Ohio. Cable address: "TIMROSCO". Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits. Canadian Division: Canadian Timken, St. Thomas, Ontario.

CIRCLE 203 ON READER SERVICE CARD